UNITED STATES DEPARTMENT OF AGRICULTURE
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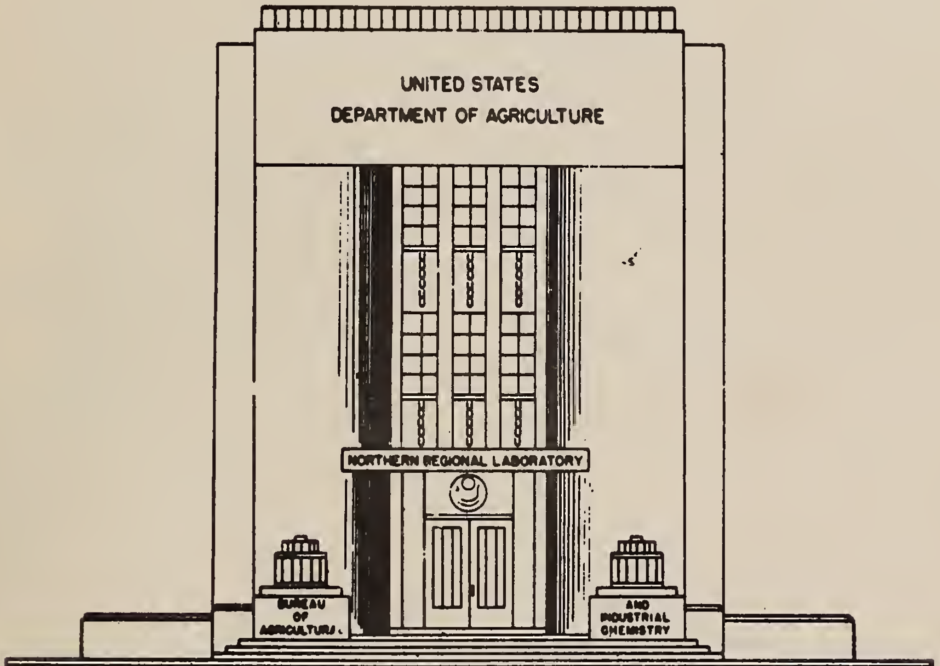
Bureau of Agricultural and Industrial Chemistry

THE SMALL RURAL INDUSTRY--A STUDY OF THE POSSIBILITY OF MAKING INSULATING BOARD FROM STRAW

PART II

EXPERIMENTAL DEVELOPMENT--PLANT DESIGN AND OPERATION



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Part II

Experimental Development--Plant Design and Operation

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INTRODUCTION

A previous publication entitled "The Small Rural Industry--A Study of The Possibility of Making Insulating Board from Straw," U. S. Department of Agriculture Circular 762, discussed the problems in developing a process for a small rural industry and its establishment. Of several processes described therein, Process No. 3 appears to present the one most practical and likely of success. The present publication presents in detail (1) the laboratory and pilot-plant data on which Process No. 3 is based, (2) plant location and suggested plans for layout of plant, (3) a description of the machinery required in operating the process including necessary design details for special machines, (4) directions for the operations of the plant, (5) cost estimates on machinery and buildings, (6) estimated labor schedules and costs, (7) estimated manufacturing and sales costs and profits, and (8) specifications for application of the board in its various uses in farm structures.

To supplement this information, it is felt that anyone seriously considering undertaking the manufacture of 25/32 inch sheathing board by the process should visit the Northern Regional Research Laboratory to learn the process details by witnessing pilot-plant demonstrations, followed by a complete discussion of the problems to be encountered in operating the process and in using the product. The process of fiberboard manufacture, even in the most up-to-date plants, is still somewhat of an art which can be learned only by some practical experience.

PRINCIPLES OF INSULATING BOARD MANUFACTURE

Insulating sheathing board must possess physical properties such that it can structurally substitute for lumber as sheathing, and at the same time provide good insulation against heat and cold. This goal is being achieved by the products of a number of manufacturers. The thermal insulating properties of the boards are due to their small air cells. It follows, then, that the board with the most air cells in ratio to its thickness is the best insulating material; in other words, the lighter the board in weight per square foot, the higher its insulating efficiency. Structural strength properties depend upon the number of fibers in the board and how well these are bonded together, so that, in general, the denser the board, or the greater its weight per square foot, the greater its strength. The problem of insulating board manufacture is, therefore, to obtain the best balance between strength and insulating values.

Many laymen suppose that the strength of insulating board is provided by adding adhesive or binding agents such as glue or resins to the board. These agents are not used for producing commercial insulating board. The strength of the board depends on properties of the fibers as developed by cooking and by mechanical refining procedures and to the methods and machines used in felting the fibers to form the board.

Two main types of fiber are required: (1) Springy, rather coarse fiber bundles graduated in lengths from 1/16" to 1" with the main portion 1/4" to 1/2" which comprise 60 to 70 percent of the board and (2) fine, shorter fibers. In the manufacturing process described, fiber lengths and proportions of long and short fibers are controlled by (1) chopping the dry straw to lengths of about 1" to 1 1/2", (2) cooking conditions, (3) shredding conditions, and (4) conditions of washing. The cooking and mechanical rubbing of the fibers during shredding swells the fibers, particularly the fine fibers, to a certain extent. The board is formed by suspending the fibers in 98 parts of water and flowing the mixture onto a wire-cloth screen. As the water drains through the screen the fibers felt together to form a mat. The board at this point contains about 90 to 92 percent water and, if dried, would produce a very light-weight and good insulating product but one having low strength; however, the drying costs would be very high. The board is pressed to reduce the water content to about 75 percent. While the board is being dried, the mass of fibers shrinks together. The greatly swollen, fine fibers which wrap around the longer, stiffer fibers shrink most and bind the whole mass compactly together to produce a strong board.

The factors of cooking, fiber refining, washing, board formation and drainage rates, pressing the formed board to remove water, etc., are all interdependent. The development of the process described was, therefore, not a simple procedure but one that required extensive laboratory and pilot-plant studies. These studies led to a determination of optimum operating conditions and also to the design of special small-scale machinery required in the rural plant.

Successful industrial operation of this rural industry process requires thorough grounding in the whole technology of the procedure. A clear understanding of the purpose which each process step is intended to accomplish will not only make for good operation but is required by anyone who must make modifications in various steps of the process to suit changes in raw materials, particularly straw. For the same reason it is necessary to have familiarity with the design and operation of the equipment used in each process step.

A discussion of the experimental development of the process is therefore desirable before presenting an operating manual of the rural plant itself.

EXPERIMENTAL DEVELOPMENT OF PROCESS

It was determined from examination of commercial sheathing boards that the straw insulating sheathing board to be manufactured would be required to meet the following specifications:

Thickness	25/32 ± 1/64 inch
Density	0.26 to 0.31 as compared to water
Tensile strength	Minimum, 175 pounds per square inch
Modulus of rupture	Minimum, 200 pounds per square inch
Water resistance	Not more than 60 percent by weight of water absorbed after 24-hour immersion in distilled water

The process was first explored on a small scale, the techniques used being those described in the Appendix, page 47. These experiments showed it was possible to produce a board meeting the above specifications without much difficulty. It was shown also that the straw should be chopped before cooking in order to reduce power costs in shredding after cooking. The optimum cooking and shredding conditions were determined.

Pilot-plant experiments were then undertaken in which every detail in the manufacturing process was carefully and thoroughly studied. The size of the pilot-plant equipment in many respects closely approached the size of respective plant equipment. The design drawings for special plant equipment are based on experimental pilot-plant data.

The process variables in board manufacture may be divided roughly into (1) fiber preparation, (2) board formation, and (3) drying and finishing.

The function of each process step, as well as the description and operation of the machinery to carry it out, will be discussed. Selected laboratory or pilot-plant experimental data which have a bearing on the process variables are presented.

It should be noted that in all of the laboratory experiments and in many of the pilot-plant runs each test involved cooking the fiber, using varying conditions of time, pressure, kind and concentration of chemical, and proportion of cooking liquor to fiber, followed by shredding and washing the fiber, by making the fiber into boards, and by pressing the water from the boards under a series of graduated pressures. The boards so made were examined for drainage rates, water-holding capacity before and after pressing, tendency to warp on drying, density, and physical properties.

FIBER PREPARATION

Fiber preparation consists of chopping, cooking, shredding, and washing the pulp.

CHOPPING STRAW

Although laboratory experiments showed that it was possible to cook and shred whole straw, about twice as much power was required to shred the cooked fiber as when the straw was chopped to lengths of 1 to 1 1/2 inches before cooking.

Several types of agricultural ensilage cutters were tested to determine which showed the highest efficiency in producing a uniform length (approximately 1 1/2 inches) of dry chopped straw with little dust production. The ability of these machines to elevate the straw was also studied, inasmuch as plant design requires the straw to be elevated 15 feet to load the cooker.

Of the machines tried, one powered by a 15-horsepower motor proved to be the most satisfactory. This machine, which is equipped with an automatic, easily controlled feed, and is designed to function in the manner of an ensilage cutter and hammer mill combined, produced a uniform fiber length and operated satisfactorily over a wide range of conditions. Irregular feeding from the broken bale of straw did not materially affect the operation of the machine or the uniformity of fiber length. At a feeding rate of 5 tons per hour the amount of dust was low (4.3 percent passing a 20-mesh screen) and elevating the straw 15 feet presented no difficulty. Other makes of the same general design would undoubtedly be satisfactory.

COOKING

Cooking accomplishes several useful purposes: (1) The soluble material, comprising about 15 percent of the dry straw, is removed; (2) the straw is softened so that during the shredding operation the fiber bundles are split lengthwise with a certain amount of shortening of the fibers, but the straw does not break up into irregular particles, as happens when dry straw is shredded; and (3) desired chemical changes in the fibers cause the fibers to swell, resulting in their shrinking properly on drying.

Mild cooking conditions are desirable (1) to reduce costs of steam and chemicals, (2) to reduce the amount of wash water required to remove the chemicals, (3) to reduce the amount of stream pollution, and (4) to obtain as high a yield of usable fiber as possible from the straw. Cooking with water alone did not produce the desired fiber characteristics. Cooking either with lime or with caustic soda did produce satisfactory fibers. Lime is cheaper than caustic soda, but cooking with lime alone produced too large a proportion of fine fibers, and the lime was difficult to wash out of the pulp. Using caustic soda alone for cooking dissolved too much material, and a pulp deficient in fines was produced unless more drastic cooking conditions were used. In a long series of experiments it was shown that a satisfactory board at the lowest cost would result from cooking with 4.5 parts of quicklime and 0.25 parts of caustic soda per 100 parts of dry straw, from using a water-to-dry fiber ratio of 6:1, and by cooking in a steam jacketed digester for 1 hour at 50 p.s.i. (pounds per square inch).

All pilot-plant-scale cooks were made in a 3-foot jacketed rotary cooker which was rotated at 1 r.p.m. Approximately 65 pounds of air-dry chopped straw and 350 pounds of water (a ratio of 6 pounds of water to 1 pound of straw) were loaded into the cooker. The correct amounts of lime and caustic for the particular cooking conditions were made into a water slurry by first hydrating the lime and then adding the solid caustic and a small volume of water. This slurry was poured into the cooker; the manhole was closed; and steam was introduced into the cooker jacket with the cooker rotating. The temperature was raised as rapidly as possible to 298° F. (50 p.s.i.), the digester being vented for a short time at about 25 pounds pressure to remove air. The temperature was held at 298° F. for 1 hour; the steam line was closed; and the steam was blown from the cooker, after which the cover was removed. Cooks were made with varying proportions of lime and caustic soda. The laboratory data, indicating that 4.5 percent quicklime and 0.25 percent caustic soda on the basis of dry straw constituted the best cooking conditions, were confirmed.

WASHING COOKED PULP

In order to approximate the plant operation where waste wash water is run onto cooked pulp in the cooker blow pit, the contents of the cooker were discharged into a large pan on the floor and the hot straw was sprayed with return wash water to remove some of the chemicals. This water was then run to the sewer. The drained pulp contained approximately 88 percent water.

SHREDDING

Pulp having the proper proportion of long and short fibers and the correct degree of swelling was best prepared by the use of a hammer-mill shredder.

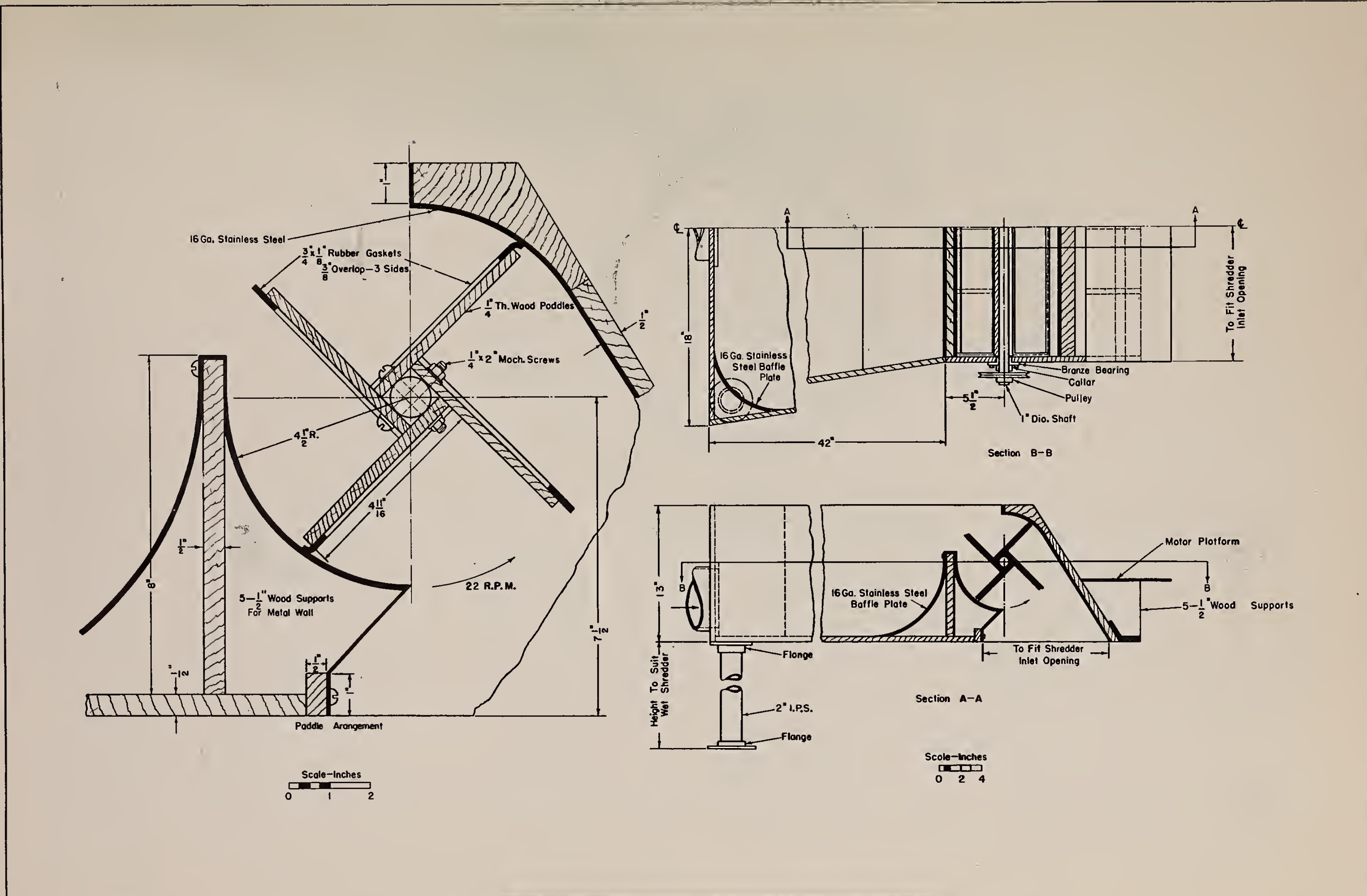

Figure 1.—Shredder metering box.

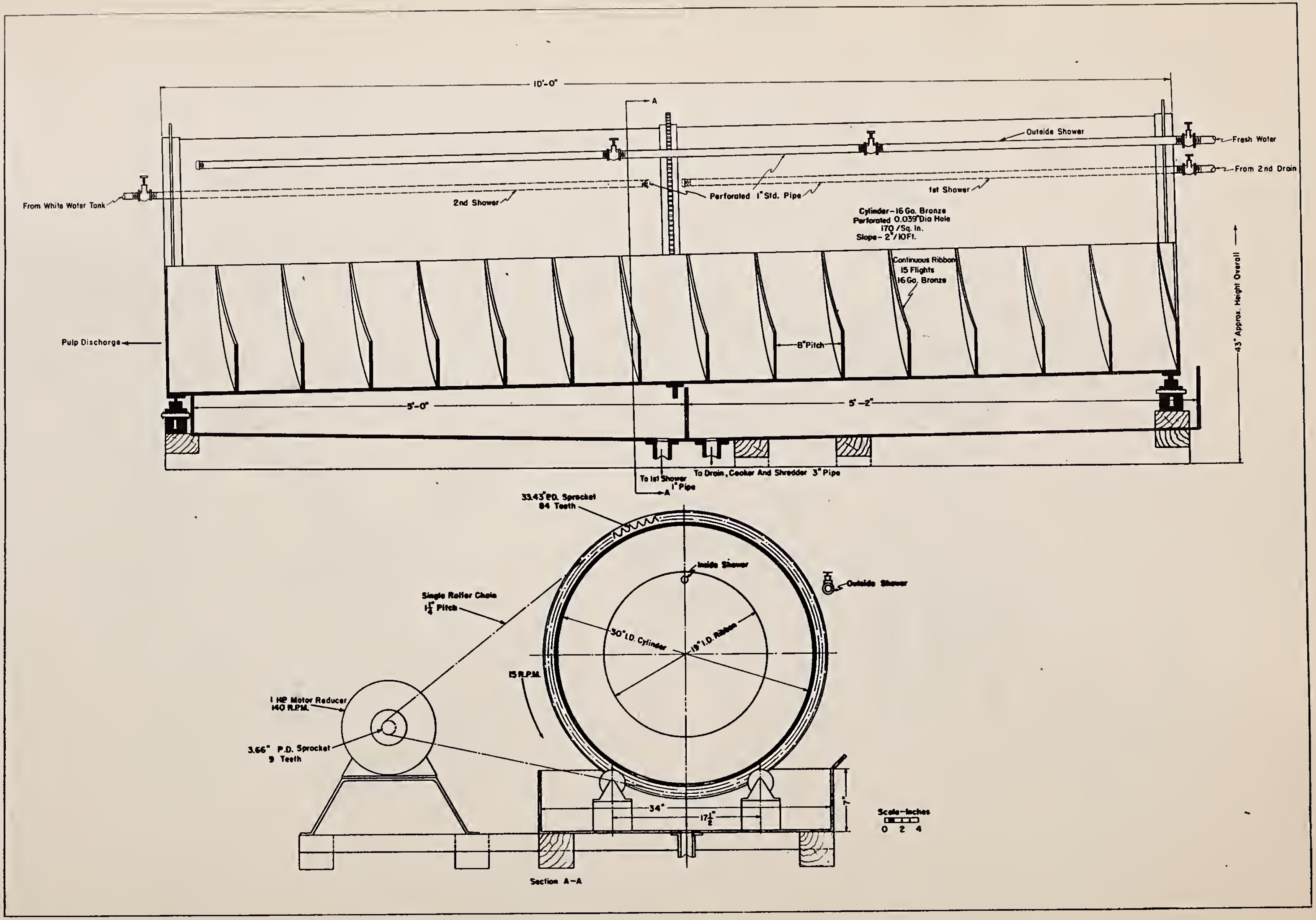

Figure 2.—Rotary washer.

The drained, partially washed straw pulp was suspended in water to produce a mixture of 98.5 percent water and 1.5 percent fiber (dry basis), was mixed thoroughly, and was then fed into the paddle-wheel metering box of the shredder with a bucket. This metering device (fig. 1) consists of a box in which a motor-driven paddle wheel is suspended in the outlet and over the feed entrance to the shredder. The device is used in many paper and board mills and produces a uniform feed of fiber and water. The use of this paddle-wheel feed doubled the rate of shredding obtained by manual feeding, and resulted in a more uniformly shredded fiber and one of higher quality.

The shredder is a hammer mill powered by a 10-horsepower motor. The 5/16" knives and a screen plate having 5/8" round holes produced the best fiber. Power consumption data as determined by watt-hour meter readings showed that standard pulp could be shredded at the rate of 12 to 14 pounds per hp./hr. The shredded pulp and the water were discharged from the shredder into a pit and then pumped directly into the rotary washer.

By using screen plates having holes of different size, the length of the shredded fibers could be varied with a fair degree of accuracy. The width and character of the rotating knives, it was found, affected the fiber characteristics. The rate of feed of fibers and the amount of water fed to the shredder were also important variables. The use of plates with smaller holes produced shorter fibers and more fines. Feeding at a higher consistency likewise produced shorter and finer fibers. The feed rate to the shredder could be controlled by the paddle wheel; the amount of water by the amount added to the cooked pulp prior to shredding.

WASHING

The soluble materials must be washed from the shredded pulp fairly completely.

Washing is one of the critical operations in the process. The soluble materials must be largely removed in the operation, but it is essential that loss of fine fiber from the washer be reduced to a minimum. The loss of too large a proportion of fine fibers will seriously lower the strength of the finished board and also affect costs by lowering the yield of usable pulp. Therefore all white water (water from board machine and press having fibers in suspension) should be pumped to a tank for re-use in the process.

Figure 2 shows the pilot-plant-scale washer. The pulp and water from the shredder flowed directly into this washer which was designed with an internal helical screw to retard the flow of pulp so as to provide ample washing and drainage time for removing most of the soluble materials. A rotation speed of 15 r.p.m. was found satisfactory. The wash water discharged from the first section of the washer was used for the preliminary wash of the succeeding cook in order to cut down fiber loss. This first section was also equipped with an outside fresh-water shower and an internal white-water shower to keep the washer screen from plugging and to add sufficient water for removal of solubles. The water draining from the second half of the screen was returned to the first section as internal shower water.

The size of the holes in the washer screens was found to be important, as also was the amount of shower water used in the first section to keep the screens from plugging. A certain portion of very fine fibers passed out through the screens with the wash water, which was desirable, yet if too large a portion of the fines was lost, the strength of the board fell below specification requirements. Of the screens hav-

ing various sizes of perforations used in the experiments, the one having 0.04" holes was most satisfactory. In operating the washer, fresh shower water was required, and even when operating with the proper type of screen it was possible, by using an excess of shower water, to lose too large a proportion of fines.

Obviously some type of control test was needed for the washing operation, not only in starting up the plant but as a check on the quality of pulp from time to time. For this purpose a simple test was developed, which is discussed under Method for Determining Fine Fiber, page 30. A satisfactory pulp should contain from 23 to 25 percent fines (as indicated by run 142, table 4).

DISCUSSION OF EXPERIMENTAL RESULTS

The data on experimental results are selected from a large number of runs and illustrate important principles in insulating board manufacture. Data of laboratory runs to prepare the board are presented in tables 1 and 2.

A review of the data in table 1 shows that a board of satisfactory properties can be produced even under a wide variety of conditions, since only run 45, where the amount of cooking chemicals was deficient, failed to produce a satisfactory board in the laboratory. The effect of changing the fiber consistency during shredding is shown by comparing runs 53 and 57. Run 57, in which a higher consistency and a smaller hole in the screen plate were used, produced shorter and more swollen fibers than run 53, so that board 57 was stronger than board 53. The shredding rate of run 57 was greater than that of run 53 owing to the higher fiber consistency, although both shredding rates were too low for economical production. By increasing the amount of cooking chemical in run 80, almost double shredding capacity was attained. On the other hand, the amounts of cooking chemicals used in runs 77, 84, and 126 were too great, inasmuch as the boards produced in these runs were too dense.

The runs shown in table 1 were exploratory and in making them Peoria city water, which is rather alkaline, was used. For economical use of rosin size and alum, as waterproofing agents, it is desirable to neutralize this alkalinity with sulfuric acid. In all of the runs shown in table 2 the fiber suspension was neutralized to a pH of 6.0 with sulfuric acid prior to board formation. In runs where sizing agents were used, these were added after neutralization, the final pH of the fiber suspension ranging from 4.7 to 5.2.

The addition of sizing agents slowed the drainage rates of the boards. This is shown in table 2 in the comparisons between runs 136-3 and 136-7 on the one hand and runs 139-2 and 139-3 on the other. When fine fibers which passed through the washer screen were added to the sized-fiber suspension before board formation, the drainage rate was still further retarded as is shown by run 139-5. The addition of these fine fibers also increased the density and tensile strength of the dried board. The board from run 139-5 was too dense because too many fines were added. In making runs 140-3, 140-4, and 140-5 the cooking and shredding conditions were the same as in runs 139-2 and 139-3. When too large a proportion of fines was lost in washing, as with board 140-3 owing to the size of the holes in the washer, the result was a board in the low-tensile-strength range of specifications. Because of the small size of the laboratory board it was not possible to make tensile-strength tests and waterproofing tests on the same board. Waterproofing tests on boards 140-4 and 140-5 were entirely satisfactory. The cooking conditions of runs 139 and 140 were adopted as most economical for pilot-plant use.

TABLE 1.--*Data on laboratory boards from exploratory runs*

(Straw chopped to about 1-1/2" length and cooked 1 hour at 50 p.s.i. in 6:1 water-straw ratio; pulp shredded as indicated; boards made from stock mixed with alkaline tap water and no sizing)

Run No.	Fiber preparation: Lime	Caustic soda	Consistency during shredding	Size of holes in shredder	Shredder capacity	Board formation and properties: Draining time	Water into drier	Thickness	Density	Tensile strength	Flexural strength
	Percent	Percent	Percent	Inches	Lb./hr.	Seconds	Percent	Inches	Gm./cc	P.s.i.	P.s.i.
45	2.5	1.00	1.0	0.625	80	174	72.8	0.770	0.264	136	370
53	3.0	1.50	1.0	0.750	80	200	74.0	0.650	0.286	200	318
57	3.0	1.50	1.5	0.625	92	120	75.0	0.723	0.280	228	418
80	3.5	1.00	1.5	0.500	166	161	75.2	0.501	0.286	231	389
77	4.0	1.00	1.5	0.500	150	211	73.7	0.488	0.314	239	400
84	4.0	1.25	1.5	0.625	136	200	74.0	0.570	0.320	207	338
126	4.5	0.50	1.0	0.625	120	220	74.0	0.649	0.303	247	350

TABLE 2.--*Data on laboratory boards from later runs*

(Straw chopped to about 1-1/2" length and cooked 1 hour at 50 p.s.i. in 6:1 water-straw ratio; pulp shredded to pass 5/8" (0.625") holes in screen at consistency of 1 percent for runs 136-3 and 136-7 and 1.5 percent for the others; shredder capacity was 100 lb./hr. for runs 136-3 and 136-7 and 156 lb./hr. for others; boards made from stock mixed with tap water adjusted to pH 6 and sized as indicated)

Run No.	Fiber Preparation: Lime	Caustic soda	Fiber passing washer screen added back	Rosin size	Alum	Board formation and properties[1]: Draining time	Water into drier	Thickness	Density	Tensile Strength	Flexural strength
	Percent	Percent		Percent	Percent	Seconds	Percent	Inches	Gm./cc.	P.s.i.	P.s.i.
136-3	5.0	0.50	Yes	0.0	0.0	237	77.3	0.701	0.271	216	306
136-7	5.0	0.50	Yes	1.5	3.8	295	77.1	0.675	0.284	274	284
139-2	4.5	0.25	No	0.0	0.0	249	74.6	0.771	0.286	266	311
139-3	4.5	0.25	No	1.5	3.8	360	75.9	0.747	0.302	269	357
139-5	4.5	0.25	Yes	1.5	3.8	405	74.2	0.696	0.317	291	369
140-3	4.5	0.25	No	1.5	3.8	314	75.7	0.800	0.271	179	238
140-4	4.5	0.25	No	1.5	3.8	344	74.3	0.820	0.268	—	—
140-5	4.5	0.25	No	1.5	3.8	344	75.8	0.782	0.283	—	—

[1] The water absorption of boards immersed for 24 hours was 56.7 percent for the board obtained in run 140-4 and 56.1 percent for board obtained in run 140-5.

Finished 3' x 3' boards made in pilot-plant runs were tested for physical properties and were used for constructing walls. Table 3 presents certain typical results which bring out important points concerning the shredding and washing operations and the bearing of these on finished board strengths. The pulps used for the boards discussed were cooked and shredded in the standard manner as shown. The screen on the washer was, however, larger than that required (0.04" perforations) so that too large a proportion of fines was lost in washing cooks 140-1 and 140-2 and cooks 141-1 and 141-2. In the case of cooks 142-1 and 142-2 the wash water from the washer was pumped over an inclined screen having perforations of 0.04" and the fines collecting on the screen were fed back into the shredder as cook 142 was shredded.

The yield of pulp in cook 142 was 64.5 percent. Cook 140, shredded at almost the same rate, gave a 61-percent yield. Cook 141, however, was shredded at a more rapid feed and the yield dropped to 58.5 percent. It will be noted that board 140-2 was low in density and in strength as compared with boards 140-1, 142-1, and 142-2. This board was deficient in fine fibers, indicating the nonuniform washing of cook 140. Boards 141-1 and 141-2 were satisfactory in strength, but the density of both boards was high despite the large loss of fine fibers in washing. This reflects the fact that crowding the shredder by a fast feed produces a larger portion of fine fibers. Boards 142-1 and 142-2 were satisfactory in every respect. Figure 3 shows two full-scale photographs of these fibers ready for board making. The ruled lines are spaced 0.5". These fibers may be used as comparison standards. Table 4 shows the amount of fines in the pulps of cooks 140, 141, and 142 as determined by the rocking screen method (see under Testing Methods, page 29).

BOARD FORMATION

Having produced fibers of the proper character, the next step in processing was felting the fibers, in water suspension, on a wire cloth as uniformly as possible. Good appearance, strength properties, and uniform insulating value are dependent to a very great extent on the uniformity with which the fibers are felted during board formation. The long fibers tend to clot together so that when the board is pressed and dried a lumpy product results if felting conditions are not properly adjusted. Thus, in producing a board of uniform thickness and density, it was necessary to provide means for delivering a definite weight of fiber into the board machine. This condition was met by adjusting accurately the proportion of fiber and water in the suspension going to the board machine, and providing an arrangement for metering accurately a definite volume of the suspension required to prepare each board. It was also necessary to add waterproofing chemicals to the fiber suspension. Finally the wet board was pressed to a known and definite moisture content before being dried, not only to permit the lowest drying costs but also to insure uniform physical properties. The equipment required in the pilot plant for these operations consisted of a stock tank, metering head box, board machine, and hydraulic press. A description of this equipment and of the operations in board formation follow.

STOCK TANK AND METERING HEAD BOX

The 500-gallon steel stock tank and the specially designed stock metering head box used in the pilot plant are shown in figure 4. The stock tank is supplied with a gate-type agitator and is connected through a 3-inch pipe to a centrifugal stock pump (3" inlet, 3" outlet) so that the stock mixture can be recirculated in the tank or pumped into the metering head box. The metering head box, which was specially designed, is of wood and holds the exact amount of fiber at 2-percent consistency (98

Figure 3.—Full-scale views of satisfactory wheat straw pulp fiber. Ruled lines spaced $\frac{1}{2}$ inch.

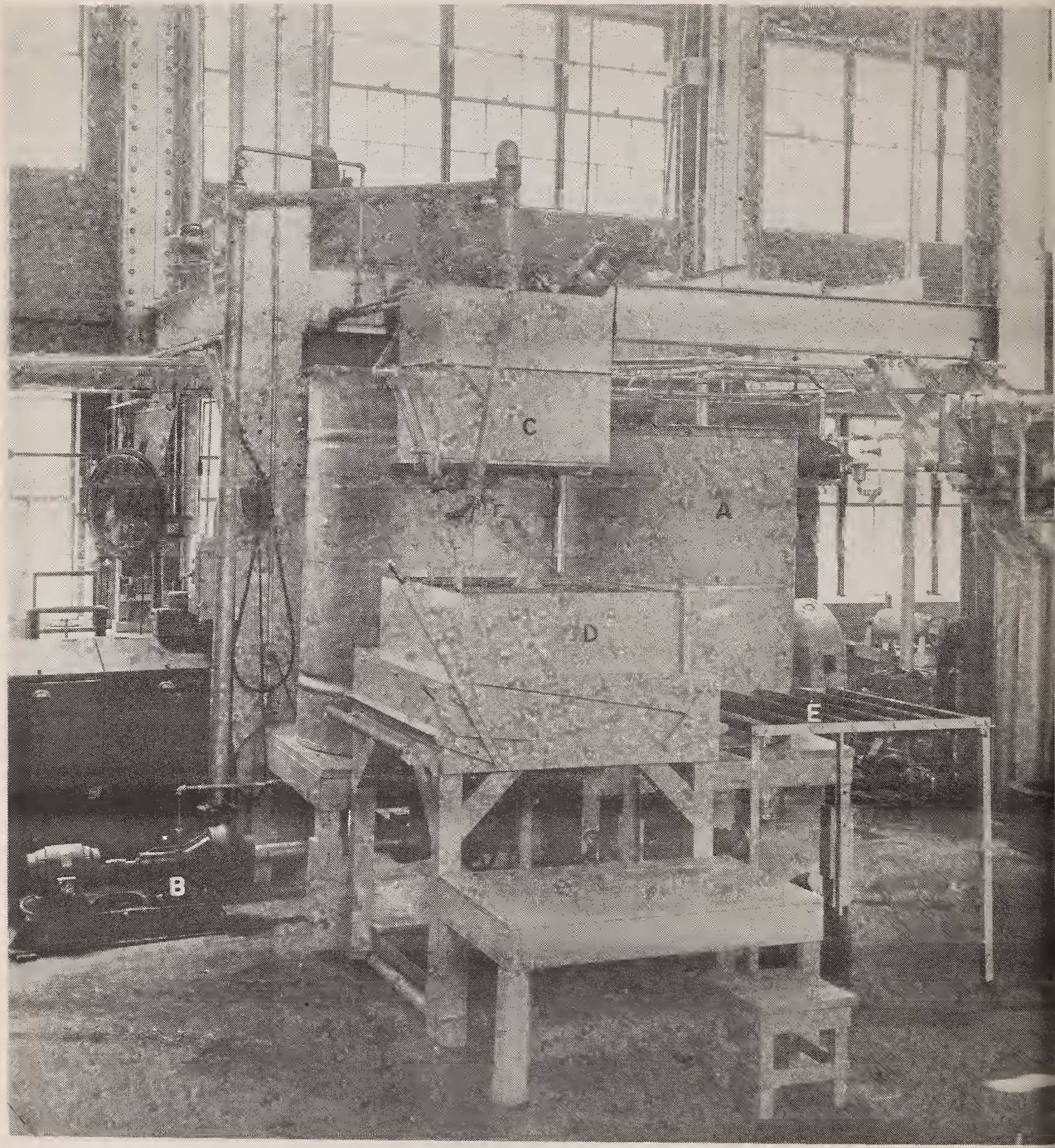

Figure 4.-Stock tank and metering head box assembly: stock tank(A), pump(B), metering head box(C), board machine(D), table rolls(E).

TABLE 3.--*Data on pilot-plant boards (3' x 3')*

(Straw chopped to about 1-1/2" length and cooked 1 hour at 50 p.s.i. with 4.5 percent lime and 0.25 percent caustic soda in 6:1 water-straw ratio; pulp shredded to pass 5/8" (0.625") holes in screen at 1.5 percent consistency; fines lost in washing added back as indicated; boards made from stock mixed with tap water adjusted to pH 6 and sized with 1.5 percent rosin size and 3.8 percent alum)

Run No.	Fiber Preparation			Board formation and properties						
	Shredder capacity	Yield of fiber for board from dry straw	Fines lost in washing added back	Draining time	Water into drier	Thickness	Density	Tensile strength	Flexural strength	Water absorption in 24 hours
	Lb./hr.	Percent		Seconds	Percent	Inches	Gm./cc.	P.s.i.	P.s.i.	Percent
140-1	156	61.0	No	87	77.0	0.694	0.270	215	266	53.8
140-2	156	61.0	No	91	78.0	0.790	0.238	108	134	55.9
141-1	205	58.5	No	85	76.4	0.612	0.320	205	315	56.7
141-2	205	58.5	No	87	78.0	0.686	0.291	200	269	49.5
142-1	147	64.5	Yes	127	78.0	0.650	0.289	185	287	56.3
142-2	147	64.5	Yes	127	77.8	0.667	0.272	205	281	55.2

TABLE 4.--*Determination of fines in washed pulp by rocker screen method*

Run No.[1]	Through shredder at consistency of [2]	Fines recovered	Time sample was rocked	Remarks
	Percent	Percent	Minutes	
138	1.0	5.47	3	Too low consistency during shredding
139	1.5	13.90	3	Additional 3 minutes of shaking increased fines 30 percent
140	1.5	23.80	6	Added fines retained in cloth bag
141	1.5	18.30	6	No fines added back
142	1.5	23.60	6	Added fines retained on 0.04" screen

[1] All cooks were made similarly.

[2] Shredder could not handle pulp of 2-percent consistency.

percent water and 2 percent dry fiber) to produce a finished board of the correct specifications. It is provided with an overflow pipe to the stock tank so that the volume of stock mixture in the metering head box is automatically controlled. The valve system is such that opening the valve to drain the box closes the valve on the inlet pipe to the box from the pump. During the operation of board formation the stock in the tank is constantly circulated, either to the metering head box or, while this is draining, back into the tank. A fresh water line is provided for adding water to the stock to adjust its consistency.

The pulp, containing approximately 94 percent water, was discharged from the rotary washer directly into the stock tank; and sufficient water, based on the tank calibration in inches, was added to produce a consistency of approximately 2.25 percent. The tank agitator and stock pump both were started to insure thorough mixing. A 20-percent solution of sulfuric acid was added to the pulp and the pH, as determined by the use of "Accutint" test paper, was adjusted to 6.0. Dry rosin size (1.5 percent on the basis of the weight of dry fiber in the tank, previously weighed out into a pan and dissolved in a little hot water) was added to the agitated stock. After the size had been stirred with the stock for at least 15 minutes, 3.8 percent of papermakers' alum (crystalline aluminum sulfate) based on the weight of dry fiber and dissolved in hot water was added. This amount of alum usually was sufficient to adjust the pH between 4.5 and 5.2 in the stock solution, a necessary condition for good sizing. After 10 to 15 minutes' stirring the stock solution was tested with indicator paper to check the pH. The consistency and freeness of the stock were determined, and the amount of water necessary to give exactly 2-percent consistency was added to the tank from the fresh-water line. After about 15 minutes' additional stirring, the operation of board

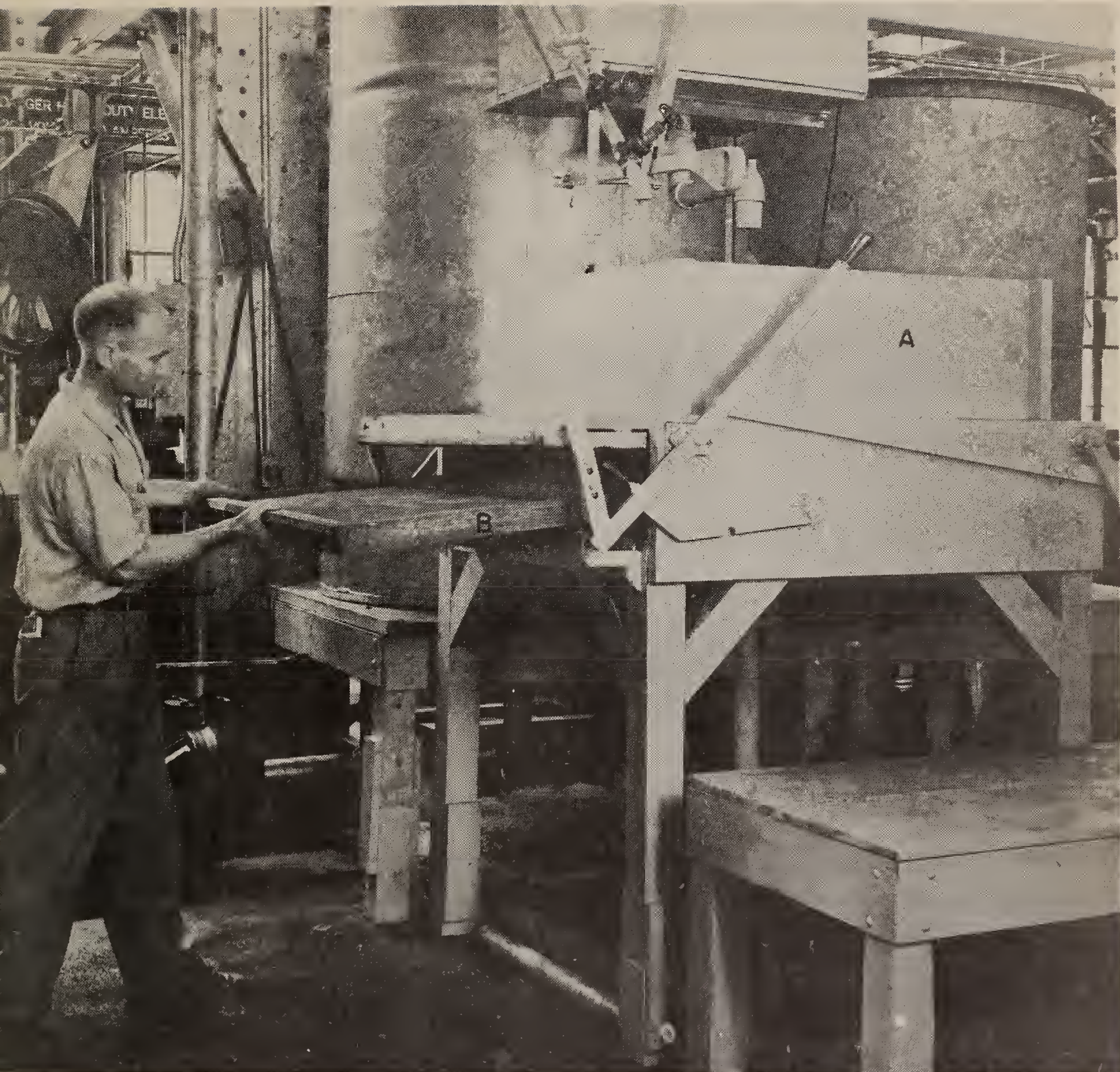

Figure 5.—Pilot plant board machine: board machine (A), screen on which board is formed (B).

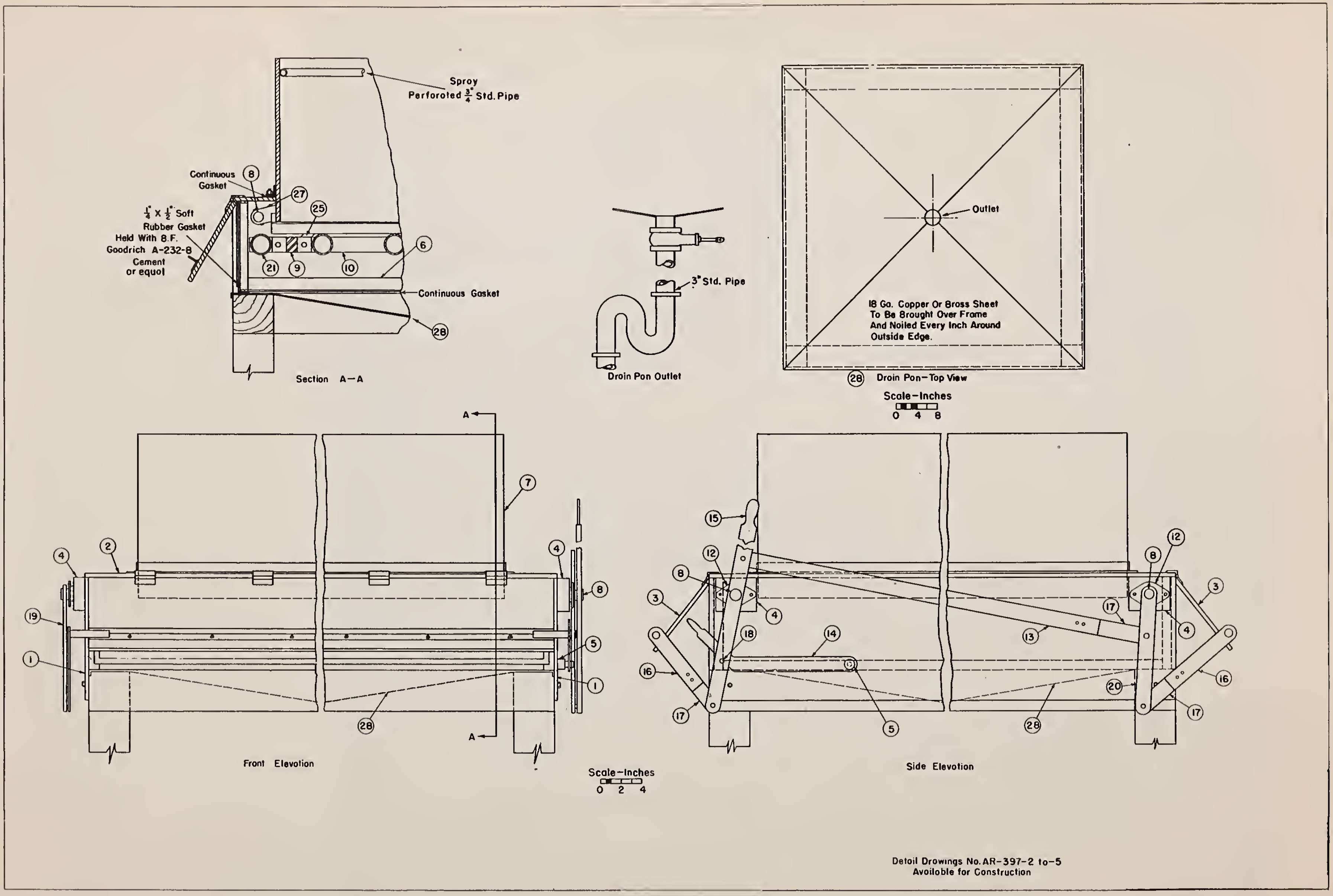

Figure 6.—Board machine for 4'X4' boards.

formation was undertaken. The freeness test is a check on the stock drainage characteristics.

A full discussion of the methods will be found under Testing Methods.

BOARD MACHINE AND THE OPERATION OF BOARD FORMATION

The pilot-plant board machine shown in figure 5 is the result of design studies, since no commercial machine of this character was available. This machine produced a wet board 3' x 3', inasmuch as this was the largest size which could be pressed by available laboratory equipment. The wooden machine, shown in the photograph, proved unsatisfactory because of shrinkage and warping, but served its purpose for obtaining experimental and design data. It was later replaced by an improved unit, constructed of brass, on which the design of the proposed plant machine shown in figure 6 is based. The board to be manufactured in the rural plant is 4' x 4' in the wet state. This wet board shrinks approximately 0.25 inch during drying, producing a finished board 3' 11 3/4" x 3' 11 3/4".

The board machine includes a square box, of two sections, capable of holding about twice the volume of stock suspension required for forming the board. The sheet-metal bottom of the lower and larger section slopes gently from the sides toward the center, and at the lowest point is attached to a 3-inch pipe, fitted with a quick-opening valve, for drainage. The lower end of this pipe is immersed in water, and thus the slight water leg formed during drainage produces some suction on the wet board. The board is formed on a screen which is inserted through a door comprising one side of the lower section and is supported by iron table rolls with the screen frame directly below the vertical sides of the upper section. After the board is formed, the screen carrying the wet board may be pushed out of the machine through a similar door on the opposite side, opening onto table rolls, and thence into the press.

The operations of board formation were as follows: The machine was drained to a level just below the table rolls. The doors were opened and a screen was rolled into place, after which the doors were closed and locked into place with a lever arm. The mechanism for closing the doors raised the table rolls and screen and sealed adjacent surfaces to each other. Fresh water was next introduced into the machine until it reached a level about 2 inches above the screen. The quick-opening valve on the metering head box was opened to allow the stock to flow into the box. The flow period was about 30 seconds (with stock of 300 seconds Schopper-Reigler freeness), after which time the valve in the water leg was opened. The water drained through leaving a mat of fibers on the screen. Some of the fibers tended to cling to the sides of the box and small intermittent streams of water from a shower pipe extending around the four inner walls washed them down.

When the board had drained (about 180 seconds) the doors were again opened and another screen was introduced, the screen holding the wet board (approximately 92 percent water) being pushed out onto the table rolls at the opposite side. The operation of wet board formation was then repeated, the metering head box having been refilled by change of the valve position when the stock flow for the preceding board was stopped.

In a square box such as was used, there is a tendency for the fiber to be non-uniformly distributed, particularly to the four corners of the box. To overcome this difficulty a small octagonal spreader (fig. 7), made of tinned iron and having the

lower 3/16 inch of the sides alternately turned outward and downward, was attached just below the outflow point of the pipe from the metering head box. The stock suspension flowed over this spreader and was thrown farther where the sides were turned outward. By experimenting with different shapes of spreader it was possible to arrive at the present design, which permits the stock to be distributed uniformly, with good board formation, when the outward-turned sides faced the corners of the box.

The door openings in the first board machine were such that the 3' x 3' wet board contained only sufficient fiber to produce a dry board 5/8 inch thick. The later design permits formation of a board 25/32 inch, the required thickness.

Time studies of the board-forming operation showed that a 5-minute schedule was practicable. On this basis, 4,500 square feet of finished board could be produced in 24 hours. The time-studies data are shown in table 5.

TABLE 5.--*Time studies on board formation operations in pilot plant*

Operation	Maximum time permitted	Actual time required
	Seconds	Seconds
Push in new screen	15	10
Close door	15	10
Run fresh water on screen	30	30
Run in pulp	30	30
Drain pulp	180	90-120
Open door	15	10
Push out board	15	10
Total	300	220

PRESSING THE WET BOARD

The screen holding the board formed in the board machine was rolled into the pilot-plant hydraulic press and pressed at 25 p.s.i. Pressing for about 1 minute reduced the moisture content from 92 to 75 percent. This pressing operation was necessary not only to reduce the amount of water to be evaporated in the drier, but also to obtain a board of proper density and physical strength.

It was necessary to confine the edges of the wet board during the pressing operation and for this purpose a square angle iron, made in two parts, was clamped around the edges of the board. The board remained on the screen on which it was formed during both the pressing operation and the drying operation which followed.

When a board formed and pressed as described was dried, the edges swelled for a distance of about 1/2 inch toward the center and hence they were appreciably thicker than the board proper. If this condition had not been corrected, it would have necessitated trimming the board by sawing to secure a satisfactory product, an additional

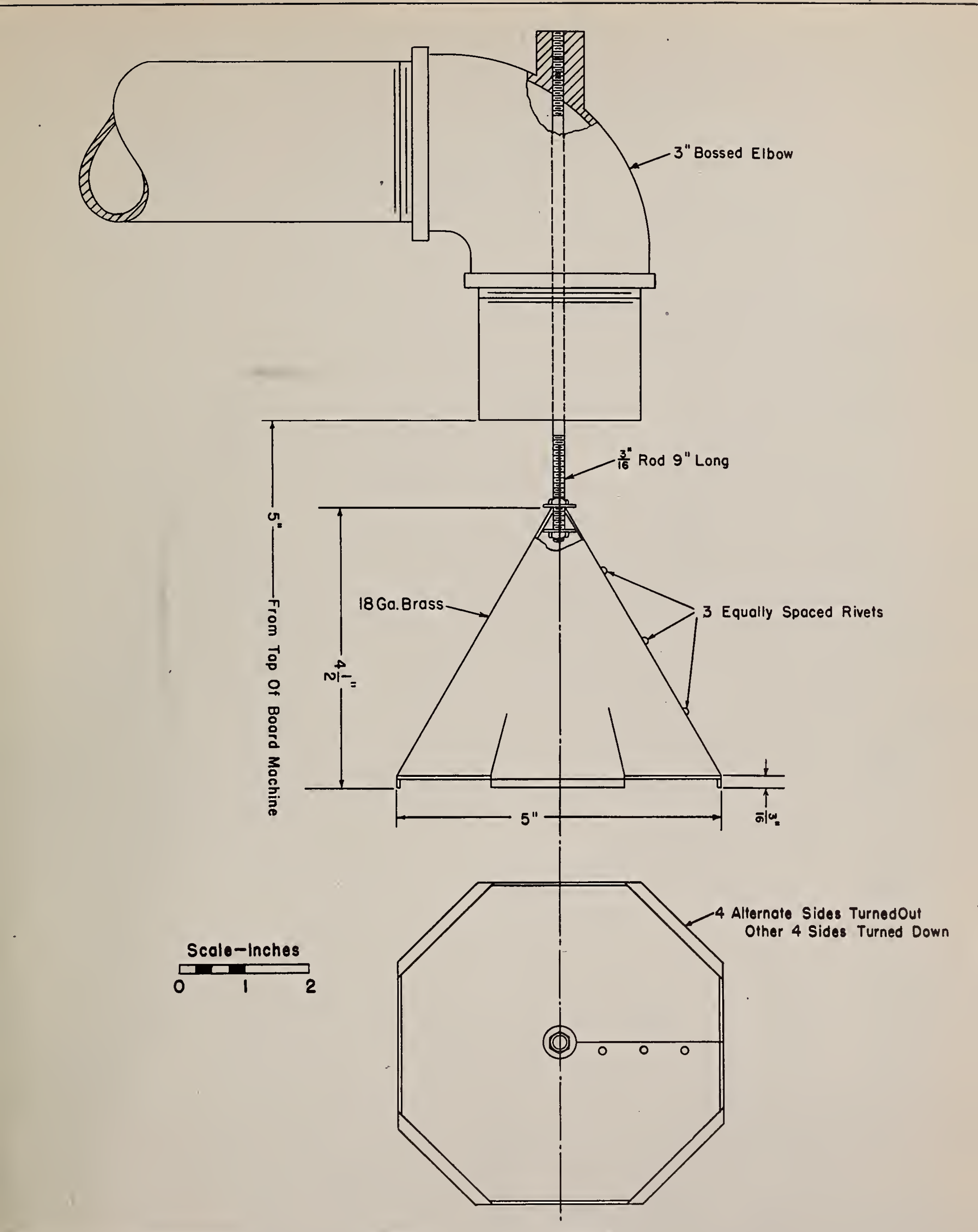

Figure 7.—Pulp spreader.

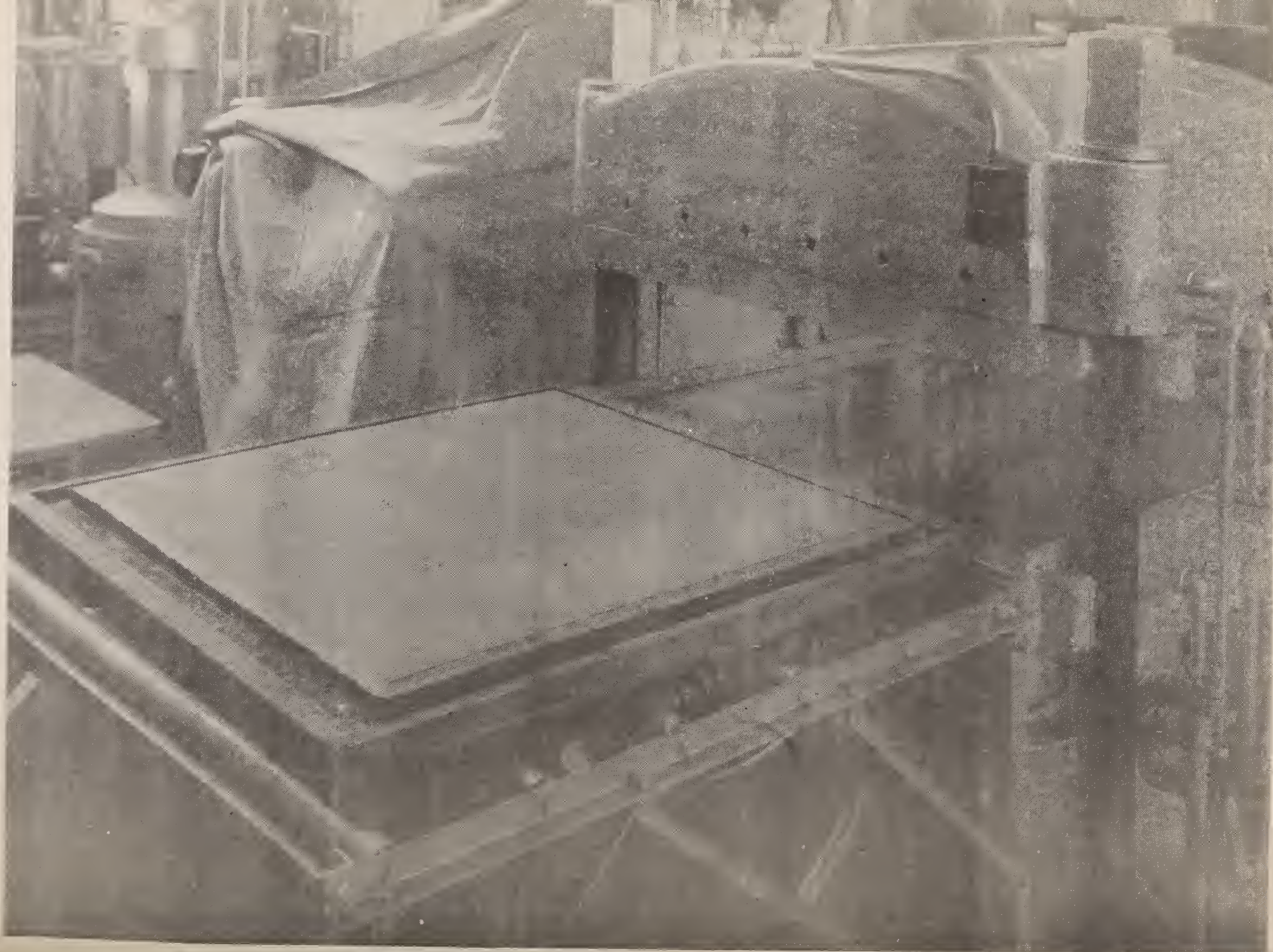

Figure 8.—Board with compressed edges.

expense in operations. Experiments to avoid this situation showed that if the edges were compressed slightly more than the main portion of the board, the edges would swell to almost the thickness of 5/8 inch during drying. By securing a small wedge-shaped strip to each bottom edge of the upper platen of the press it was possible to compress the edges of the board properly. A board with compressed edges is shown in figure 8.

DRYING AND FINISHING

DRYING

The plan of plant operation requires an 8-hour drying schedule. Studies were conducted in the pilot-plant drier to determine the conditions required to meet this drying time. This drier is of the tunnel type in which air is circulated by three 18" propeller fans. Heat is supplied by fin-type heaters, one unit being above the ceiling over the loads and another between the two loads of boards. These heaters were supplied with steam at 120 p.s.i. The design of this drier is essentially that of the plant drier shown in figure 15. Operating at a temperature of 250° F. and an air velocity across the boards of 500 feet per minute, the drying time was about 10 hours, but at a temperature of 320° F. with all vents closed except the outlet vents for vapor, the drying time was reduced to 7 hours. A free-vane pneumatic controller was used to control the temperature of the drier and 14 thermocouples were installed for determining the temperature of different parts of the drier and to follow the changes of temperature of a number of test boards in the loads. Such equipment is not required for plant operation. It appears that with an adequate heating system and uniform air circulation of 500 feet per minute, satisfactory drying conditions can be obtained by simply maintaining a reasonably constant stream pressure of about 100 pounds in the heating system.

In the operation of the pilot-plant drier the pressed boards were loaded one on top of another on a dolly, a full load being 10 boards. Two dolly loads were then pushed into the two-compartment pilot-plant drier. Heated moist air was circulated over the boards until their moisture was reduced to about 5 percent. The screen racks were so constructed that when the racks and boards were piled on the drier dolly, air circulated freely and uniformly on both sides of each board. Drying was continued until all thermocouples in the test boards registered at least 235° F. This condition was attained after 7 hours of drying.

Weight changes of the boards indicated that all but two contained 4 percent or less of water and those two contained 10 percent. Data from a typical drying experiment are shown in table 6.

FINISHING; TESTS ON ASPHALT EMULSIONS

When the dollies were removed from the drier the boards, while still hot, were sprayed on one side with an asphalt emulsion and placed one on another to make a pile of 20 boards and allowed to cool. The water in the emulsified asphalt was vaporized and taken up by the piled boards. In this manner the boards were seasoned to a moisture content of about 10 percent.

Table 7 presents data on the use of eight different commercial asphalt emulsions. Product C proved best from the standpoint of economy and performance. Very likely other emulsions on the market would be equally satisfactory.

TABLE 6.--*Pilot-plant drying test*

Time	East end		West end		East pile of boards					West pile of boards				
	Thermocouple No.		Thermocouple No.		Thermocouple No.					Thermocouple No.				
	5 Wet bulb	7 Dry bulb	1 Wet bulb	3 Dry bulb	9	11	13	15	17	19	21	23	25	27
Boards in at	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
9:25 a.m.	139	250	138	228	—	—	—	—	—	—	—	—	—	—
9:40 a.m.	151	286	139	256	—	105	102	—	110	113	124	126	148	107
10:00 a.m.	165	300	155	280	132	145	138	136	141	143	151	155	182	143
10:15 a.m.	168	307	160	286	146	157	148	147	152	152	165	165	190	152
10:30 a.m.	168	310	160	286	152	168	154	153	160	157	175	170	191	156
10:45 a.m.	168	313	160	289	155	175	160	156	166	159	186	176	190	157
11:00 a.m.	168	315	161	295	155	177	164	160	170	163	194	184	188	160
11:30 a.m.	168	318	160	300	160	180	169	165	177	173	205	200	189	165
12:00 noon	168	323	160	304	165	184	174	170	187	184	217	214	189	171
12:30 p.m.	165	323	160	308	173	190	177	174	203	195	229	225	202	177
1:00 p.m.	165	326	160	311	179	198	180	175	217	205	246	236	(1)	183
1:30 p.m.	165	327	159	312	187	218	185	176	227	212	265	244	—	190
2:00 p.m.	165	328	158	315	197	236	190	179	236	219	282	250	—	197
2:30 p.m.	164	328	162	317	206	256	195	181	244	225	298	253	202	205
3:00 p.m.	164	330	163	318	216	280	202	182	251	231	315	260	213	217
3:30 p.m.	163	330	163	320	224	305	213	187	261	240	325	275	219	226
4:00 p.m.	163	332	164	322	229	334	251	227	313	250	331	276	230	261
4:25 p.m.	161	332	165	323	237	335	325	315	335	257	333	282	238	313

[1] Poor electrical connection (repaired between readings).

Note: Air was continuously directed from east end of drier at a velocity of 500 feet per minute by anemometer reading. All vents in drier were closed except outlet vents for moisture escape.

The thermocouples were placed as follows: Nos. 27 and 19 were imbedded in the center of the boards next to the top and bottom boards, respectively, of the west dolly load; Nos. 17 and 9 were placed in similar positions in the east load; Nos. 21, 23, and 25 were placed in the center board of the west load and Nos. 11, 13, and 15 were placed in an identical arrangement in the east load. Nos. 21, 25, 11, and 15 were inserted three inches from the ends of the board while Nos. 23 and 13 were imbedded in the middle of the respective boards.

TABLE 7.--*Tests with emulsified asphalts*

Product tested	Solids content	Consistency of sample	Dilution with water	Color of diluted emulsion	Ease of application by spraying	Asphalt used (on dry weight of board)	Increase in density of dry board	Color of dried board	Ease of separating boards[1]
	Percent					Percent			
A	58.30	Liquid	Dilution not possible	—	Very difficult. Could not brush on	4.42 5.80	0.014 0.017	Black	Difficult; parts of board broken
B	62.81	Liquid	Dilution not possible	—	Readily applied	3.80 3.07	0.013 0.009	Black	No sticking
C	72.70	Soft solid	50 gm. in 125 cc.	Black	Readily applied	1.75 2.20	0.021 0.021	Black	No sticking
D	48.93	Similar to tooth paste	50 gm. in 125 cc.	Brown	Readily applied	3.42 2.36	0.039 0.027	Brown	No sticking
E	56.32	Suspension of chunks	50 gm. in 175 cc.	Brown	Readily applied	1.81 1.73	0.024 0.024	Brown	No sticking
F	66.03	Suspension of chunks	50 gm. in 125 cc.	Brown	Readily applied	2.00 1.75	0.023 0.016	Brown	No sticking
G	71.19	Suspension of chunks	50 gm. in 125 cc.	Brown	Readily applied	2.50 2.31	0.022 0.021	Brown	No sticking
H	58.80	Liquid	50 gm. in 125 cc.	Brown	Readily applied	3.70 4.23 4.31	— — —	Brown	Difficult; parts of board broken

[1] Stacked boards were dried overnight under a 50-pound weight before test was made.

THE RURAL INSULATING BOARD PLANT--AN OPERATING MANUAL

PLANT LOCATION

The plant should be located preferably in a small town in a wheat-growing area so that 1,100 tons of wheat straw can be procured each year within a hauling radius of only a few miles. The plant should be located so that the waste waters, which contain some alkaline salts and dissolved organic matter, can be run into a stream large enough to avoid serious stream pollution. The effluent from the plant will amount to only about 50,000 gallons per day, having a biological oxygen demand of 182 parts per million. This effluent is equal in oxygen demand to the sewage of a town with a population of 450. The plant will employ 11 persons and will operate three 8-hour shifts per day for 300 days per year. The plant site must provide room for the storage of approximately 1,200 tons of baled straw or 2 piles of 500 tons each and a smaller pile of 250 tons.

PLANT LAYOUT

Figure 9 shows a plan view of one possible layout of the plant which occupies a two-story frame building with a one-story storage shed attached. Figure 10 shows an elevation view of the equipment in the two-story manufacturing building. These plans show the relationship of the various pieces of equipment and indicate the locations of pumps, motors, and pipes, but do not give all piping details. Depending upon available buildings, the layout of an actual plant would, of course, vary from the plans shown. Storage space is provided for 2 months' production of finished board.

The floor space allowances in the plans for a board plant as shown in figure 9 are as follows:

	Square feet
First-floor area:	
Main plant, 40' x 50'	2,000
Straw storeroom, 16' x 24'	384
Board storeroom, 26' x 56'	1,456
Total	3,840
Second-floor area:	
Main plant, 16' x 50'	800
Chemical storeroom, 25' x 24'	600
Total	1,400

The chemicals for preparing cooking and sizing solutions are stored on the second floor, a space 24' x 25' being required.

STRAW PROCUREMENT, HANDLING, AND STORAGE

The recommendations which follow are based on extended practical experience in the strawboard industry which uses about 700,000 tons of straw annually.

QUALITY AND COLLECTION

Straw quality is exceedingly important. If the straw is collected and stored in a dry condition, there will be practically no loss during storage and the cooking conditions which are adopted may be used throughout the year without change. Dry, unde-

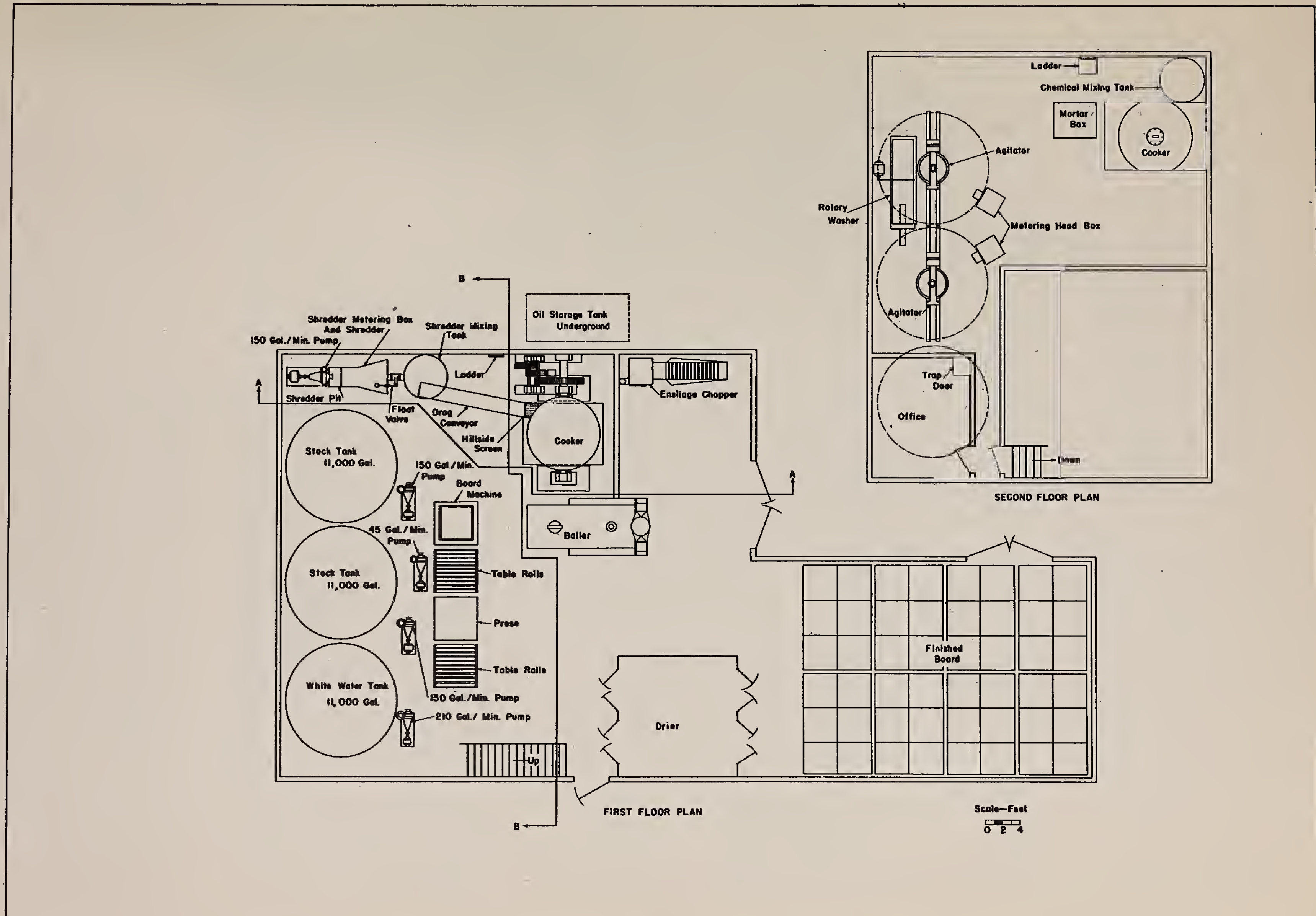

Figure 9.—Board forming plant—Floor plan.

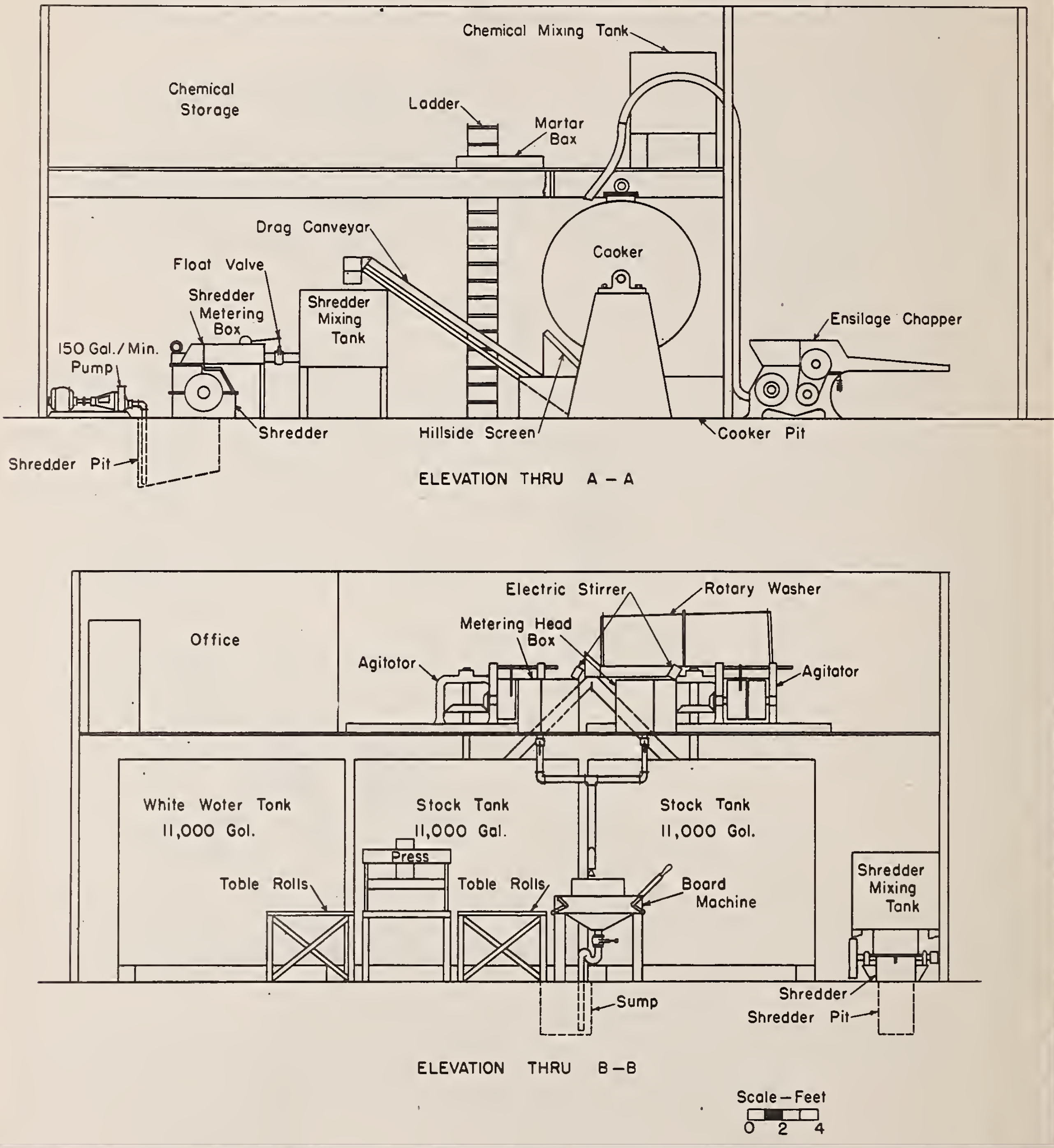

Figure 10.—Board forming plant—Elevation through sections A–A and B–B as indicated on Figure 9.

composed straw, which was used in the pilot-plant studies, produced the highest yields on cooking, and fibers so prepared were most suitable for board manufacture. Straw baled and stored in a wet condition, or in which green weeds are present at the time of baling, will ferment, causing weakening and loss of fiber. Decomposed straw cooks differently, giving lower yields and producing a heavy board unless changes in operation are made. It is evident that a standard product cannot be manufactured from day to day from straw of widely varying quality. High quality straw is extremely important and too great care cannot be exercised in observing the recommendations.

Either combine-harvested or thresher straw is satisfactory for use, but in any case the straw should be baled when it is air-dry, immediately after combining or threshing, if possible. The straw should be as free from chaff and grain as possible. In using the combine method of harvesting the cutter bar should be lowered, if possible, to produce a 3-inch stubble because the best straw is at the bottom of the stalk. If the operation of the combine does not permit low stubble-cutting, the standing stubble should be immediately mowed, windrowed, and baled with a pickup baler. Straw harvested by the combine method is relatively free from chaff and grain. If the straw is produced by the thresher method, it would be desirable to provide a thresher attachment to blow the chaff into a separate pile. The straw should be baled preferably at the time of threshing.

Standard bales 16" x 18" x 42" weighing about 70 to 80 pounds each are required for proper stacking and storage. Wire ties are probably preferable, or if twine ties are used, the twine must be strong enough to withstand storage in large piles.

It will be desirable for the plant to contract separately with each farmer for straw and to arrange for the farmer to deliver and help stack the straw at the plant. In this way the farmer will receive a higher return for his straw and labor. The best grade of straw will be assured if the farmers are properly informed of requirements.

STORAGE

Stored straw presents a fire hazard. The Western Actuarial Bureau states that for rating purposes a standard pile is considered to contain 500 tons of baled straw or 14,300 bales on the basis of 70 pounds per bale. This pile does not exceed 100,000 cubic feet in volume and is 40' x 60' and 40' high. A distance of at least 50 feet must separate the piles, and lower insurance rates are allowed for wider spacing. The stacks must be placed at least 100 feet from any building. Hazards of smoking, sparks from locomotives and from factory chimneys must be guarded against, and precautions must be taken to prevent grass fires in the vicinity. Measures for fire protection and watchman service should be provided. The night foremen should make an inspection on each shift. The area should be fenced in with barbed wire on top of woven wire fence 6 feet high.

In making the straw pile, a well-drained level area 40' x 60' is selected. The bottom of the pile is slightly larger than the top and should contain from 550 to 600 bales. In order to tie the pile securely together it is well to arrange the bales on the outside of the pile so that the ends and long sides of bales are alternately exposed. No space need be left between the bales if the straw is air-dry. The arrangement of the inner bales is not so important. Using this method, a row of 24 bales will form the outside edge of the 60' sides of the pile and 16 bales the shorter 40' sides. The pile will be 27 bales high and may be built to form a sloping top.

The sides and tops of the piles are exposed to the weather and must be protected. The simplest method now used is to cover the pile well down the sides with heavy asphalt-laminated kraft paper which can be held in place by the use of wires. These wires may be held by weights or they may be attached to stakes driven into the ground or which extend out from the lower tiers in the pile. The paper is lapped as it is laid on and the wires are placed over the lapped sections to prevent the wind from raising the paper and blowing it away. Tarpaulins are better than paper but are more expensive. The bottom bales will decompose to a certain extent and in taking down the pile a few bottom bales should be mixed in with sound bales for each cook. If heavy rains are likely to occur during piling, the pile should be covered as a temporary measure to keep moisture out. Wet bales in the interior of the pile do not have an opportunity to dry out and will ferment. This fermentation under severe conditions may lead to spontaneous combustion.

A little more than two standard piles of baled straw or a total of 1,100 tons of straw are required for the annual operation of the plant. It would be well to obtain 1,300 to 1,400 tons of straw the first year in order to offset any unexpected losses and to have some to carry over from one season to the next to offset late harvests or deficiences in supply of raw material.

PLANT OPERATION AND EQUIPMENT

THE STEAM PLANT

An 87-hp. horizontal fire-tube boiler delivering steam at 100 p.s.i. gage pressure will satisfactorily handle the process steam load for the cooking and drying operations, since boilers generally operate at 150 to 200 percent of their nominal rating. The boiler will be fully insulated and supplied with a smoke stack and necessary supports. It is assumed that the boiler will be oil-fired (103 hp. oil burner) and automatically operated. A 2,000-gallon tank buried in the ground and equipped with necessary valves serves for storage. A boiler return water system handling 20 gallons per minute at 100 p.s.i. pressure is also required. Raw water from deep wells generally requires treatment for reduction in total hardness if used as boiler-feed water. Provision is made for this treatment by the use of a 10-gallon per minute zeolite water softener. Steam for cooking is reduced by an automatic valve from 100 to 50 p.s.i. at the rotary cooker. Steam at 100 p.s.i. is used in the drier. Radiant heat from the cooker and drier is believed sufficient to heat the plant during the colder months.

CHOPPING OF DRY STRAW AND LOADING THE COOKER

Approximately 35 bales (2,440 pounds, determined by weighing at least 7 bales for each cook on platform scales) of straw are required each 8-hour shift. Sufficient straw is hauled from storage in the truck during the day and piled in the storage shed so that trips for straw after dark are not necessary.

Straw is chopped once each shift and blown into the cooker. An ensilage-type chopper, equipped with a traveling type feed belt and blower, is located in the storage shed and is arranged to chop and blow straw directly into the rotary digester.

The wires on the bales are cut and the bale is broken into segments which are fed to the traveling apron of the chopper by use of a fork. The total time required for chopping is about 30 minutes.

COOKING

A rotary globe cooker 9 feet in diameter and capable of withstanding 100 p.s.i. steam pressure is required. It rests on trunnions, is geared to rotate at 1 r.p.m. and is fitted with a manhole having a bolted cover. This cooker has sufficient capacity to cook the straw for the operation of one 8-hour shift.

The cooking chemicals are made up in the chemical mixing tank, 4' 8" high and 5' diameter on the second floor near the cooker. This tank is supplied with an electric stirrer and a small 1 1/2-hp. motor-driven 2" centrifugal pump with a delivery line running to the top of the cooker. The slaked lime required for each cook is prepared by placing 93.5 pounds of chemical quicklime (from a 100-pound sack) in a mortar box and carefully slaking the lime with water, using a hoe. When the lime has slaked and formed a putty it is shoveled into the chemical make-up tank, and 5 pounds 3 ounces of solid flake caustic soda is added. The wash-water line supplying the tank is opened, and 630 gallons of water is added (to depth of 3 feet) while the stirrer produces vigorous agitation.

Since the chopped straw contains much air and does not wet easily, it will float on the chemical solution if the latter is first added to the empty cooker. In order to place the quantity of straw (35 bales) necessary for one charge in the digester, two loadings are required, the first load being "wilted" by a short cook.

To carry out the first loading, enough straw is chopped and blown into the empty cooker to fill it (about 20 bales). The charge of cooking chemicals is then pumped into the cooker, and the chemical tank is refilled with 636 gallons of wash water which is also pumped into the cooker. The straw absorbs the solution and floating is thus avoided. The cover is bolted onto the cooker; the motor rotating the cooker is started; the steam line to the cooker is opened; and the charge is steamed about 3/4 hour while the pressure is held between 15 and 20 pounds gage. On completion of this short cook the steam line is closed; the steam in the cooker is vented to the air; and as soon as no steam comes from the vent the cover is removed from the cooker.

In the second loading, the remainder (15 bales) of the charge of straw is chopped and blown into the digester. It is believed that one wilt will be sufficient to permit placing the complete charge of straw in the cooker. However, if two wilts are used, the wilting time at 15 pounds pressure may be reduced to about 20 minutes for each.

After the complete charge of straw has been blown into the cooker, the cover is bolted on, the motor rotating the cooker is started, and the steam line is opened. When the pressure on the steam gage of the cooker reads 25 p.s.i., the rotation is stopped, the steam line is closed, and steam is vented to the air until the gage reads 15 pounds. The steam vent is then closed; the cooker is rotated; and the steam line is opened. The cooker operation is continued for 1 hour after the gage reads 50 p.s.i., and cooking is controlled at 50 p.s.i. At the end of this period the steam is shut off, the rotation of the cooker is stopped, and the steam pressure is released through the vent gradually (to keep liquor from boiling out) until steam ceases to leave the vent pipe. The cover is then removed from the manhole of the cooker, and rotation is started. During each rotation some of the cooked straw falls into the cooker pit. The cooking cycle from the time of first charging straw until the cooker is blown down will be 5 to 6 hours. The foreman is not required to watch the cooker constantly. About 20 minutes will be required to dump the cooker.

Chemicals used are 4.5 percent lime and 0.25 percent caustic soda, based on weight of dry straw, as determined by pilot-plant studies. In starting up the plant it may be necessary to make some changes in the amount of chemicals, since it has been observed that different varieties of straw or the same varieties grown under different conditions vary somewhat in their fiber qualities. During the operation of the plant, if weathered straw is used, it may be found necessary to reduce the amount of chemicals. In all cases when changing the degree of cooking, the amount of lime should be lowered, but the amount of caustic used should not be changed. When lime percentages are changed, only small changes should be made, for example, reduce the amount of quicklime from 93.5 pounds to 87 pounds, and, if the straw is still too soft, reduce the lime to 83 pounds. During cooking there is a shrinkage of about 16 percent in the straw, so that the yield of pulp is about 84 percent. The consistency of the pulp in the cooker pit is about 18 percent.

The cooker pit is a concrete box, the bottom of which is pitched away from the lower end of the drag conveyor. Cooking liquor drains from this pit by gravity through a 3" iron drain pipe extending to the outside of the building (to a sewer or other drainage system). A grid plate of 6-inch diameter, drilled with 1/4" holes, prevents fibers from clogging the drain.

After the shredding operation on each shift is started, any wash water not needed for chemical make-up is allowed to run onto the pulp still remaining in the cooker pit, so as to wash out some of the solubles at this point and filter out fine particles in the wash water before it runs to waste. This wash water is pumped over a "hillside" screen in order to separate and save the fine fibers. The construction of the screen is shown in figure 11, and its location is shown in figures 9 and 10.

SHREDDING AND WASHING

Conveyor.--The cooked pulp which has been given a preliminary washing in the pit and contains about 12 percent fiber is fed to a mixing tank supplying the shredder by means of a drag conveyor. The shredding cycle takes approximately 2 hours, and, since the cooked pulp from a complete charge consists of about 2,050 pounds of dry fiber (12 percent) and about 15,030 pounds of water (88 percent), the total weight of wet pulp to be conveyed in 2 hours is 17,080 pounds or 142 pounds per minute. It will be necessary to use a fork to assist in feeding the conveyor.

Calibration of Conveyor.--When operation of the plant is started, it will be necessary to adjust the conveyor and feed to a delivery rate of 17 pounds of dry straw or, at 12-percent consistency, 142 pounds of cooked pulp per minute. For purposes of calibration a cook is made as described, and arrangements are made to run fresh water through the hillside screen onto the cooked pulp at a rate of 75 gallons per minute by adjusting the outlet valve.

Provision is made at the delivery end of the conveyor to have the cooked pulp fall to the floor rather than into the mixing tank. Tests in the pilot plant indicate that a 4-tine fork load will average 10 pounds of wet pulp. Twenty fork loads would, therefore, be required as a feed per minute. The number of conveyor flights required to hold this quantity divided by the number of flights in the conveyor will indicate the number of circuits needed per minute.

The conveyor is operated at the estimated necessary speed, and the flights are kept substantially full by the operator. At the end of 5 minutes the pulp conveyed is

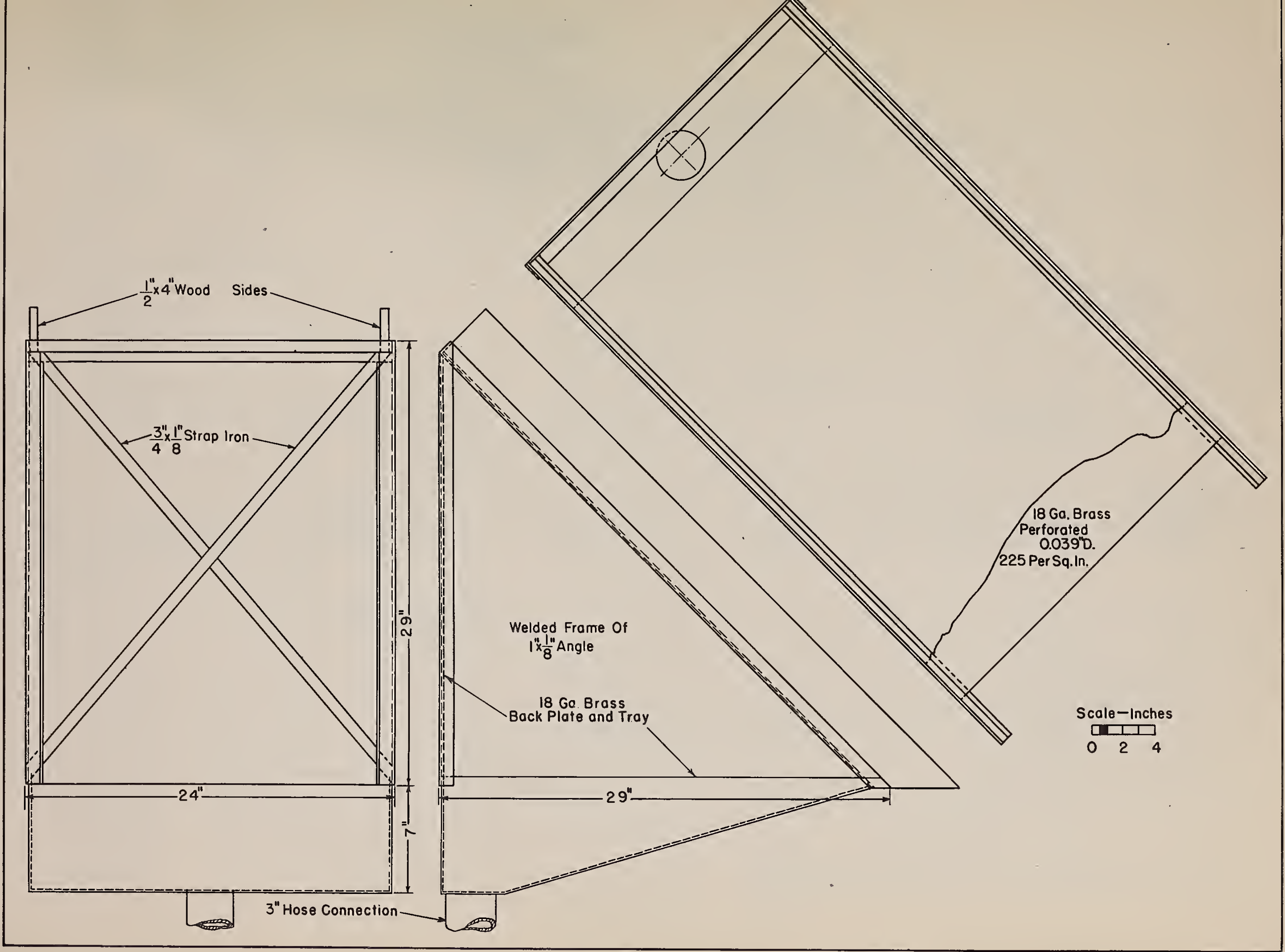

Figure II.—Hillside screen.

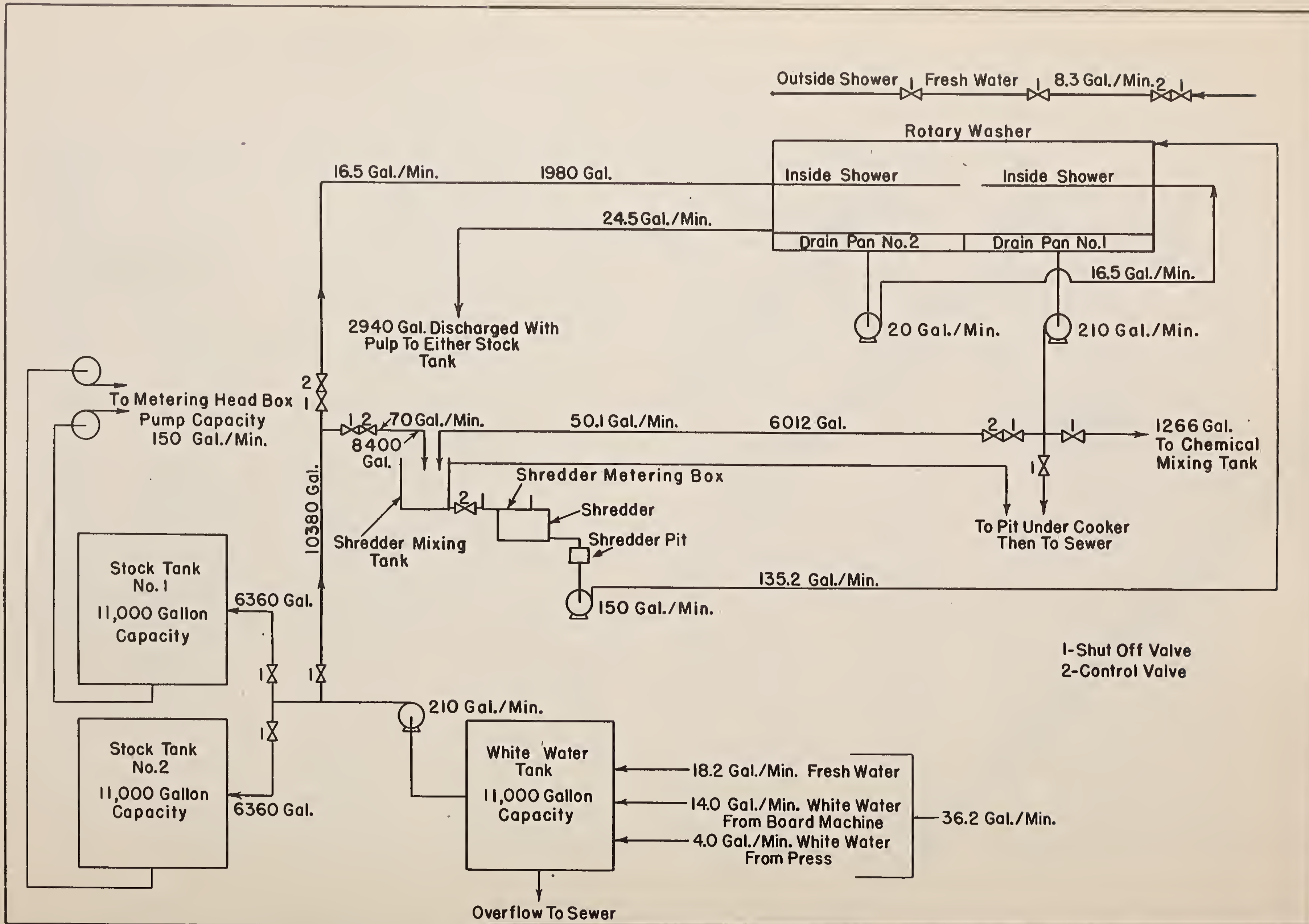

Figure 12.-Water-balance flow sheet for 8-hr. cycle.

weighed and sampled for moisture. On the basis of the results the conveyor speed can be adjusted correctly. While operating the shredder it will be necessary to keep the conveyor constantly loaded, since the uniformity of shredding depends upon a steady feed. It may be found that a fork with bent tines, which can be used to rake the pulp onto the conveyor, is better than an ordinary fork. Pilot-plant studies on this phase of the operation have not been possible.

Shredding.--Dilution water from the rotary washer and the white water tank are pumped into a 500-gallon shredder mixing tank. The pulp that is on the drag conveyor empties into this mixing tank, where it is mixed by an electric stirrer. This tank is connected through a 3" pipe to a short flume which ends in a metering device (shown in floor plan, figure 9) operated with a ratiomotor. A float valve located in the 3" pipe controls the feed of pulp. The metering device discharges the mixture of fibers and water at a uniform rate directly into the shredder. The rotation of the metering paddle wheel must be adjusted so as to meter all of the pulp mixture into the shredder in 2 hours' time. At a 1.5-percent consistency of the pulp the wheel should be set at 22 r.p.m. The preferred consistency for shredding is 1.5 percent, but variations between 1.5 and 1.75 percent are permissible.

The shredder screen under the rotating knives is 30" x 24" in size, and the shredder is powered with a 40-horsepower motor. It is probable that a screen plate having 5/8" holes will be found to produce the proper kind of board stock. The shredded pulp discharges into a sump pit from which it is pumped by a centrifugal pump into the first compartment of a rotary washer on the second floor.

Washing.--The design details of the rotary washer system located on the second floor are shown in figure 2. The rotary washer is cylindrical and is covered with a bronze screen, perforated with 0.039" holes. Inside this cylinder is a bronze 15-flight helical screw to provide sufficient retention of the pulp for proper washing. The washer has a slope of 2 inches in 10 feet from the entrance to the exit end, rests on trunnions, and is rotated at 15 r.p.m. by means of a chain gear driven by a 1-horsepower motor.

White water, 16.5 gallons per minute, is pumped from the white water tank into the internal shower pipe at the exit of the washer. The use of white water not only conserves fresh water, but the acid in this water assists in neutralizing any alkali remaining in the pulp. The water from the pulp so showered is collected in a tray under the washer where it flows into a 20-gallon-per-minute centrifugal pump to be pumped into the internal shower pipe at the entrance end of the washer. This water together with water draining from the entering pulp is collected in a tray and from there runs into a centrifugal pump of 210-gallon-per-minute capacity to be returned to the shredder mixing tank, the cooker pit, or the chemical make-up tank. An outside shower delivering fresh water is provided for the whole length of the washer and arranged by valves into three sections. This shower is required for keeping the holes in the washer clear and to provide for sufficient washing. It is believed that one or at most two sections of the fresh-water shower will suffice in preparing adequately washed pulp. Excessive fresh shower water will result in the loss of too large a proportion of fines, producing a board deficient in strength.

The pulp to be washed is pumped into the entrance end of the washer from the shredder sump by means of a 3" trash pump. The washed pulp discharges at approximately 6 percent consistency directly into either of the two stock tanks, depending upon which is being filled. Prior to starting the shredding operation, 5,800 gallons of white water is pumped into the tank to be filled with pulp.

Water Schedule.--To prevent loss of chemicals and fiber and to minimize stream pollution it is necessary to use as little fresh water in the system as possible. The water balance schedule is, therefore, very important and is intimately tied in with the whole operating schedule. Figure 12 shows a water-balance flow sheet for one shift's operations. This flow sheet indicates the source and disposition of the various streams of water both in gallons per minute and gallons per 8-hour shift. Table 8 shows the volume of water in the two stock tanks and the white water tank during each hour of three shifts. This water balance indicates the loss of 42 gallons of white water to the sewer on each shift, which flows from a 10,200-gallon water-level overflow line located on the white water tank. An additional 614 gallons is lost in the processing during each shift.

Calibration of Water Line Valves.--The lines from the white water tank to the exit compartment of the washer and to the shredder mixing tank, as well as the lines from the tray under the entrance compartment of the washer and to the blowpit and chemical make-up tank, are all supplied with two valves. The first valve is for opening and closing the line. The second is for regulating the rate of flow. To calibrate these valves water is pumped from the white water tank, or the washer tray, and the rate of flow measured by catching the water in a calibrated container. When the valve setting (indicated on the water schedule flow sheet, figure 12) is obtained, the handle of the valve is removed. The fresh water lines to the washer are supplied with dual valve control and thus the flow rate is regulated.

Starting Shredding and Washing Operations.--To start the shredding operation, open the valves on the lines from the white water tank to the washer and to the shredder mixing tank, and start the pumps on the washer. When water begins to flow from the washer into the shredder mixing tank, start the shredder, the metering paddle wheel, and the drag conveyor; also open the fresh-water shower valve on the washer and the valve on the line from the washer to the cooker pit, the operating valve on the latter line being adjusted to just prevent overflow from the shredder mixing tank. After the shredder has been operating for a few minutes examine the shredder pulp for fiber quality by squeezing pulp in the hand to note drainage and "feel" of the pulp. Also suspend a small sample in water in a glass pie plate to note fiber length and proportion of fines, making comparisons with standard fibers shown in figure 3. Inspect operation of washer on second floor. The operation should then be automatic and its uniformity will depend to a great extent upon the uniformity with which the cooked fiber is conveyed to the shredder.

It is desirable from time to time to make a test on the percentage of fines in the washed pulp, using the rocker screen method. This is particularly the case should the board be too heavy or too light or should it be deficient in strength.

At the end of the shredding operation, stop the pump on the white water tank, close the valves delivering water to the shredder mixing tank, and shut off the fresh water shower on the washer. When the water in the washer trays has been cleared, shut down the washer pumps.

SIZING AND ADJUSTING CONSISTENCY OF BOARD STOCK

Just before the shredding operation starts, the circulating pump on the stock tank to be filled is started. This tank contains 5,800 gallons of white water previously added from the white water tank. When the shredding and washing operation is complete, the tank will contain approximately 8,650 gallons of water and 1,562 pounds

TABLE 8.--*Regulation of white water supply for 24-hour schedule*[1]

Time, three shifts	In white water tank	In stock tank No. 1	In stock tank No. 2	From drainage sump	To shredder tank and washer[2]	From washer with pulp	Chemical tank	Remarks
O'clock	Gallons	Gallons	Gallons	Gallons	Gallons	Gallons	Gallons	
8:00	4,400	9,200	Empty		Empty		634	
8:45	6,029	8,337	5,800	1,629	Empty		634	Start of shedding
9:00	5,279	8,050	5,800	543	1,293	368	634	operation
10:00	2,279	6,900	6,156	2,172	5,172	1,470	Empty	End of shedding
10:45	29	6,037	7,578	1,629	3,879	1,103	Empty	operation
11:00	572	5,750	8,644	543	Empty		Empty	
12:00	2,744	4,600	8,644	2,172	Empty		Empty	
1:00	4,916	3,450	8,644	2,172	Empty		Empty	
2:00	7,088	2,300	8,644	2,172	Empty		Empty	
3:00	8,070	1,150	8,644	2,172	Empty		634	556 gallons water
4:00	10,200	Empty	9,200	2,172	Empty		634	added to tank No. 2[3]
4:00	4,400	5,800	9,200		Empty		634	
4:45	6,029	5,800	8,337	1,629	Empty		634	Start of shredding
5:00	5,279	6,156	8,050	543	1,293	368	634	operation
6:00	2,279	7,578	6,900	2,172	5,172	1,470	Empty	End of shredding
6:45	29	8,644	6,037	1,629	3,879	1,103	Empty	operation
7:00	572	8,644	5,750	543	Empty		Empty	
8:00	2,744	8,644	4,600	2,172	Empty		Empty	
9:00	4,916	8,644	3,450	2,172	Empty		Empty	
10:00	7,088	8,644	2,300	2,172	Empty		Empty	
11:00	8,070	9,200	1,150	2,172	Empty		634	556 gallons water
12:00	10,200	9,200	Empty	2,172	Empty		634	added to tank No. 1[3]
12:00	4,400	9,200	5,800		Empty		634	
12:45	6,029	8,337	5,800	1,629	1,293	368	634	Start of shredding
1:00	5,279	8,050	6,156	543	5,172	1,470	634	operation
2:00	2,279	6,900	7,578	2,172	3,879	1,103	Empty	End of shredding
2:45	29	6,037	8,644	1,629	Empty		Empty	operation
3:00	572	5,750	8,644	543	Empty		Empty	
4:00	2,744	4,600	8,644	2,172	Empty		Empty	
5:00	4,916	3,450	8,644	2,172	Empty		Empty	
6:00	7,088	2,300	8,644	2,172	Empty		Empty	
7:00	8,070	1,150	9,200	2,172	Empty		634	556 gallons water
8:00	10,200	Empty	9,200	2,172	Empty		634	added to tank No. 2[3]

[1] At the end of each shift there is 10,200 gallons of water in the white water tank. At the beginning of the next shift 5,800 gallons is transferred to the empty stock tank. The schedule shown applies strictly only every other day; on other days stock tank No. 2 instead of stock tank No. 1 is emptied during the first and third shifts.

[2] The white water used, together with about 100 gallons of fresh water entering washer, is recirculated through the shredder and washer. Eventually about 2,940 gallons re-enters system with washed pulp, and 1,266 gallons with cooking chemicals. The remainder is used to rinse pulp in cooker pit and then goes to sewer.

[3] About 656 gallons of fresh water added each shift.

of stock (dry basis) which is at approximately 2.12-percent consistency. The necessary 20-percent sulfuric acid solution to produce a pH of 6.0 is added and after 5 minutes the pH of the solution is tested.

Next add 23 pounds 12 ounces of dry rosin size, previously weighed out and dissolved in 50 gallons of hot water (a glycerin drum supplied with a branched 1/8-inch pipe line leading into each of the stock tanks and supplied with valves is suitable). After stirring for 10 to 15 minutes add slowly 60 pounds 2 ounces of papermaker's alum previously dissolved in 50 gallons of hot water (wooden barrel supplied with lines and valves), and after 15 minutes' additional stirring determine the pH. If the pH is above 5.2 add sufficient alum solution to bring it into the range 4.7 to 5.2. At this time take a consistency sample, immediately filter it and place filter pad in a drying oven (250° F.). After 1 hour weigh the filter pad, calculate the consistency and from this calculate and add the number of gallons of white water required to produce a consistency of exactly 2 percent in the tank. About 600 gallons of water will be required. After stirring for 15 minutes the stock is ready for use on the board machine.

BOARD FORMATION SYSTEM

This system consists of: 1. Two wooden stock tanks, each supplied with an agitator and a 3" trash pump and necessary piping to circulate the stock to the metering head box and back into the tank.

2. Two metering head boxes (fig. 13), each attached to a stock tank. The use of only one metering head box in the system requires a piping and valve layout too complicated for easy operation. Each metering head box is provided with the two-way valve system indicated in the drawing. The outlet pipe from each metering head box is connected to the common stock-delivery pipe feeding the board machine. The outlet of this delivery pipe is central to and located 5 inches above the board machine top. To this pipe is attached the pulp spreader (fig. 7). The metering head boxes are constructed to hold the exact volume of stock suspension at 2-percent consistency to form one board.

3. A wooden white water tank of 11,000 gallons capacity to receive return water from the board machine and press. This tank is supplied with a pump delivering 210 gallons per minute. It is connected to the washer, to the stock tanks, and to the shredder mixing tank. An overflow 1" pipe line is provided at the 10,200-gallon level, which runs to the sewer.

4. A board machine (fig. 6)[1] that will produce a finished dry board 4' x 4' in size. The stock flows from the metering head box over the pulp spreader (fig. 7). In starting the operation, some changes in the shape of this spreader may be required in order to produce a uniform distribution of stock into the corners and center of the machine. Table rolls extend from the board machine to the press and from the press to the drier skids to carry the screens containing the wet board.

5. Galvanized wire screens with welded steel frames (fig. 14) on which to form the board and carry it through the whole operation. These screens are a considerable item of expense, since 480 are required.

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[1] For those who plan on building a plant, blueprints showing all construction details of the board machine are available at the Northern Regional Research Laboratory, Peoria, Illinois.

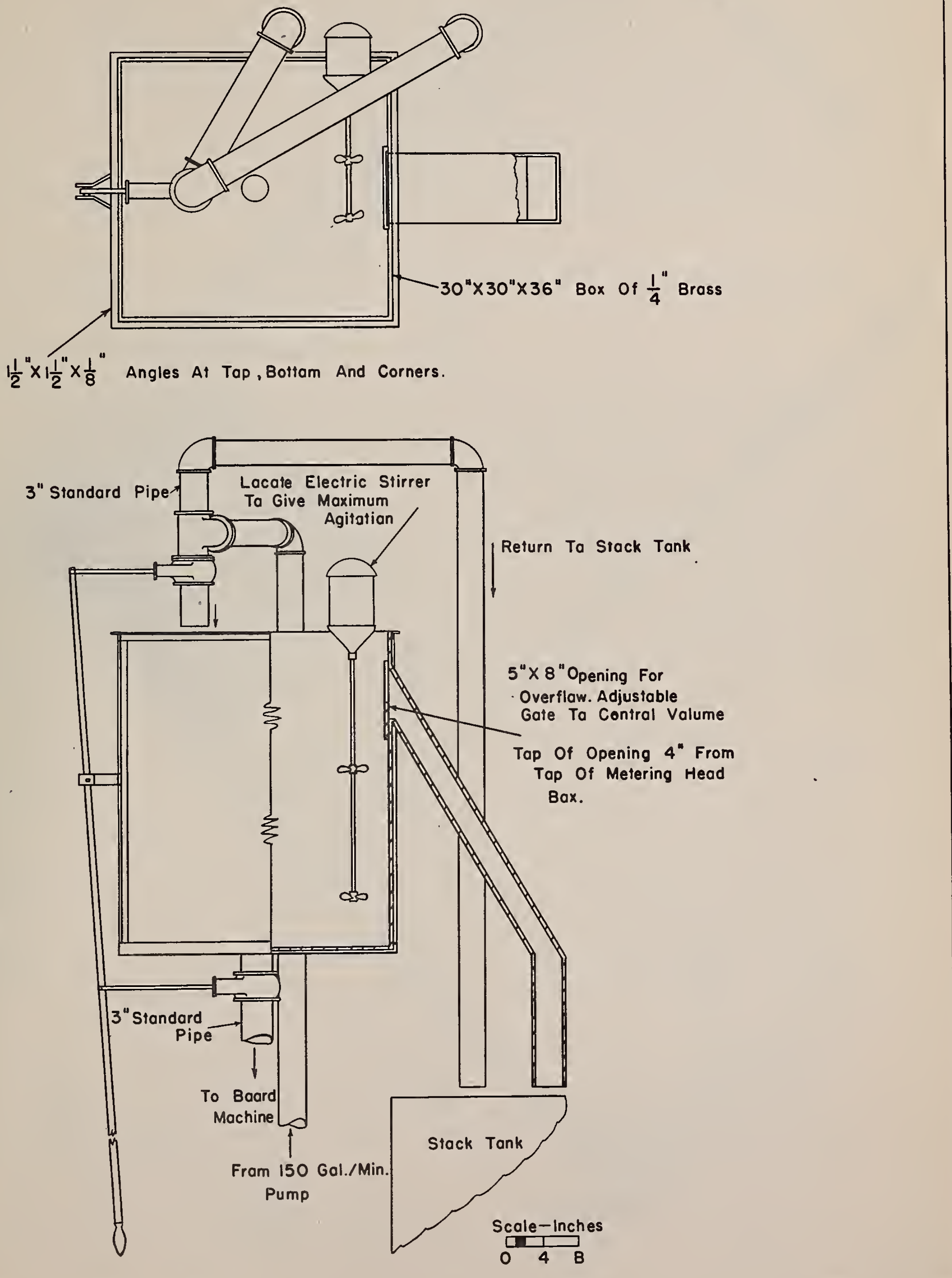


Figure 13.—Metering-head box.

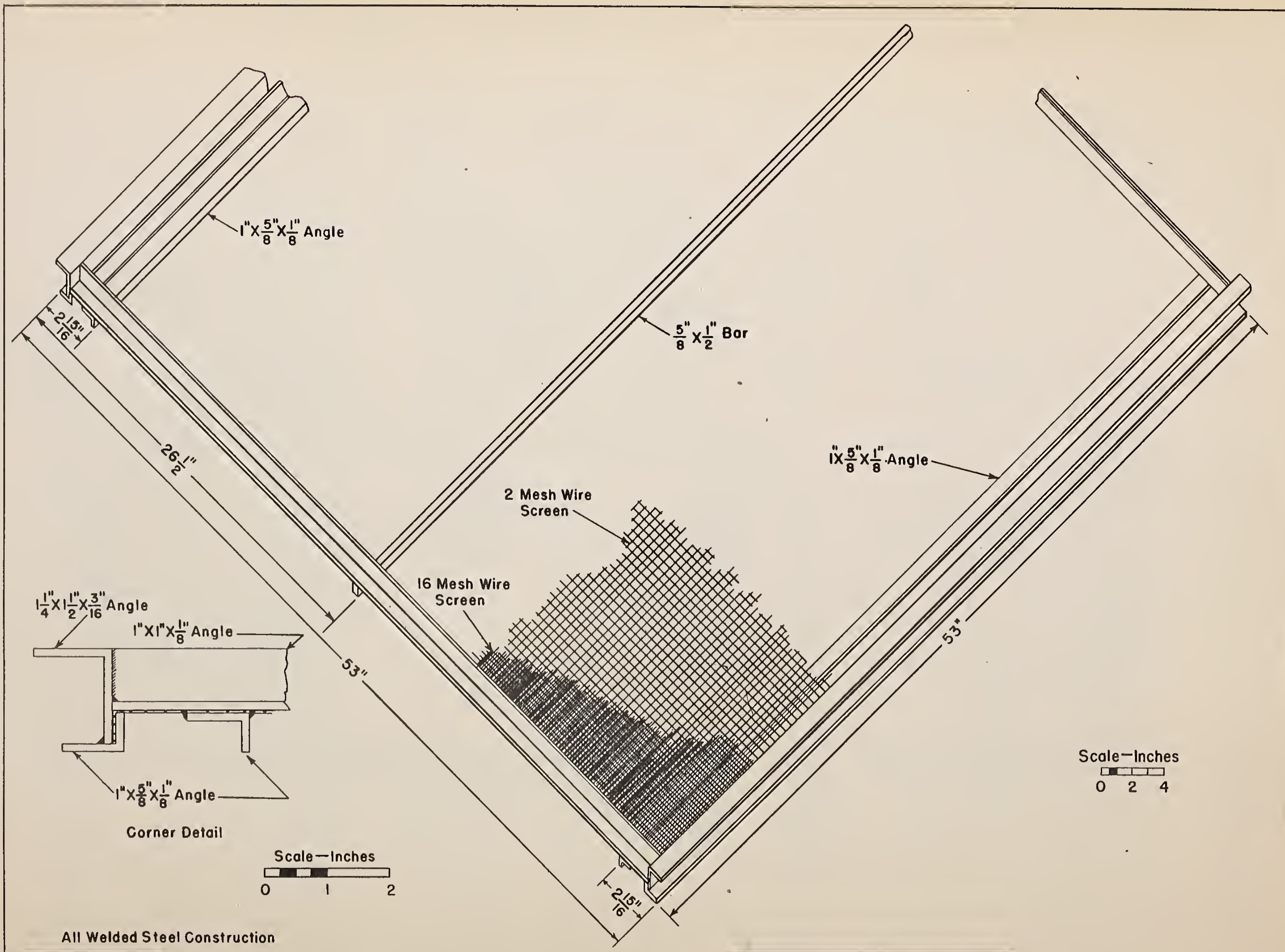


Figure 14.—Wire screen tray.

6. A hydraulic press for removing free water from the wet board. A standard 30-ton, 4-post hydraulic press is modified to provide the necessary details for pressing this board. This press has a platen area of 54" x 54" and is designed for a maximum daylight opening of 9 inches. The total travel of the ram is 8 inches at a speed of 21 inches per minute. The ram is provided with a pressing mechanism whereby the edges of the board are confined during pressing. This mechanism is controlled by springs so that on the upward stroke the edges of the board are not ruptured when the pressure is released. Both top and bottom platens are reenforced for a pressure of 25 p.s.i. The bottom platen is provided with rollers on 3" centers which support the screen trays during pressing. The press is operated by a hydraulic pump and 5 horsepower electric motor. This pump is connected to the press by a flexible high-pressure hose. The pump is also provided with controls which automatically cut off the motor at the desired pressure. The floor area required for the press is 60" x 60" and the area for the pump is 20" x 22".

7. A small hoist for lifting the screen carrying the pressed board onto the skids for drying.

OPERATION OF BOARD MACHINE AND PRESS

A skid load of 24 empty screens is placed at the feed end of the board machine. To start, the operator closes the valve on the drain line and with the lever opens the side gates of the machine. An empty screen is pushed into place. The gates are closed and locked with the lever; water is run in from the fresh water line to a depth of about 2 inches above the screen; and a quick-opening valve on the metering head box supplying the machine with stock is opened. When the head box has drained (about 30 seconds), the valve is closed, which opens the valve permitting the head box to be refilled from the stock tank. The valve on the drain line is opened and while the water drains (about 180 to 190 seconds), the wet board is formed. Fibers clinging to the sides of the box are washed down once or twice by pressing the push-buttom valve on the shower line. When drainage ceases, the operator closes the valve on the drain line, opens the gates on the machine, and introduces another empty screen.

In this and each succeeding instance during operation, the empty screen pushes the screen on which a board has been formed out through the opposite gate onto table rolls connecting with the press. The gates are then closed and the operations of forming another board are undertaken. During the draining period the operator pushes the screen carrying the wet board into the press. If a screen is in the press, it, in turn, is pushed onto table rolls at the far side. The press is opened and closed by a manually-operated foot valve. A timing device is used to indicate the proper interval. After the press is closed, the operator, using the small electric hoist, removes the screen carrying a pressed board from the table rolls onto a drier skid, which has a capacity of 24 boards. A "handy" man removes the fully loaded skids to a position ready for introduction into the drier and keeps the board machine operator supplied with skids, each carrying 24 empty screens.

The cycle of board formation is 5 minutes, within which the operator has ample time to carry on the operations of board machine and press without haste. It will, of course, be necessary to work the proper sequence of motions into a smooth routine of little lost motion and effort. With this schedule it is possible to form 96 boards per 8-hour shift.

The white water from the board machine and the press runs into a small sump and is pumped continuously into the white water tank.

When the board machine is first operated, the shape of the spreader over which the stock solution flows from the metering head box may have to be changed slightly. This may be done by bending the sheet metal with the fingers. It is essential that stock flows uniformly into the corners of the machine, and that when the wet board is removed from the forming box it is substantially of uniform thickness and does not contain surface hills and valleys of more than 0.5" from the highest to the lowest areas. This may require several hours' experimentation. The wet board can be re-used by placing it in a tank and reducing it again to a suspension of 2-percent consistency.

DRYING

The tunnel drier shown in figure 15 is arranged with doors opening both into the plant proper and into the storage shed. This drier will hold six skid loads of 24 boards each; three loads deep and two loads wide. The drier is emptied at the end of a shift by moving the skid loads with a lift truck into the storage shed and is loaded from the other side. The drying time is 7 hours or a little more. Any incompletely dried boards may be re-dried during the shift when the drier is shut down, but still hot. It is necessary to operate the drier only 16 of the 24 hours per day. It is not necessary to have vents for introducing fresh air into the drier, since the forced circulation and vents to the outside remove the moisture formed in the drying operation. The screens are built so as to provide channels for air to circulate freely on each side of the board to insure uniform drying (fig. 14).

The handy man removes each full skid load of boards from the press and sets them in line for the next drier load, consisting of 144 boards. The drier is supplied with 100 p.s.i. steam pressure and must be practically up to temperature (320° F.) at the time of loading after the shut-down shift.

FINISHING THE BOARDS WITH ASPHALT EMULSION; PILING

Room is provided in the storage shed for 2 months' production. The skid loads of hot board from the drier are moved in position to be piled, and each board, before it is piled, is sprayed with 2.7 pounds of asphalt emulsion. The emulsion, which may be purchased in 55-gallon drums, must be sprayed on uniformly so as to present an even, pleasing, and uniform black upper surface when dried.

In making a pile, the boards are placed directly one on top of another while warm or even hot. The moisture in the emulsion is taken up by the board so that it comes into equilibrium with normal humidity. The floor of the storage room is bare earth. The bottom board is not placed directly on the ground, but on 2 x 4's spaced 2 feet apart. The boards are piled 152 high. The 24 empty screens are piled on a skid and moved every hour to the board machine. As the boards are piled, they are inspected. Any broken or substandard board is piled in a separate pile to be sold as "seconds."

DIRECTIONS FOR CHEMICAL MAKE-UP AND TESTING

COOKING CHEMICALS

Directions for making up the lime and soda for cooking have been given under Cooking (Plant Operation and Equipment). Caustic soda in flake form is purchased in 50-pound drums. *It is a dangerous chemical which will burn the skin and damage clothing. It must not be allowed to get in the eyes.* In weighing out the flake caustic and placing it in the chemical make-up tank, use rubber gloves and wear goggles. Wash

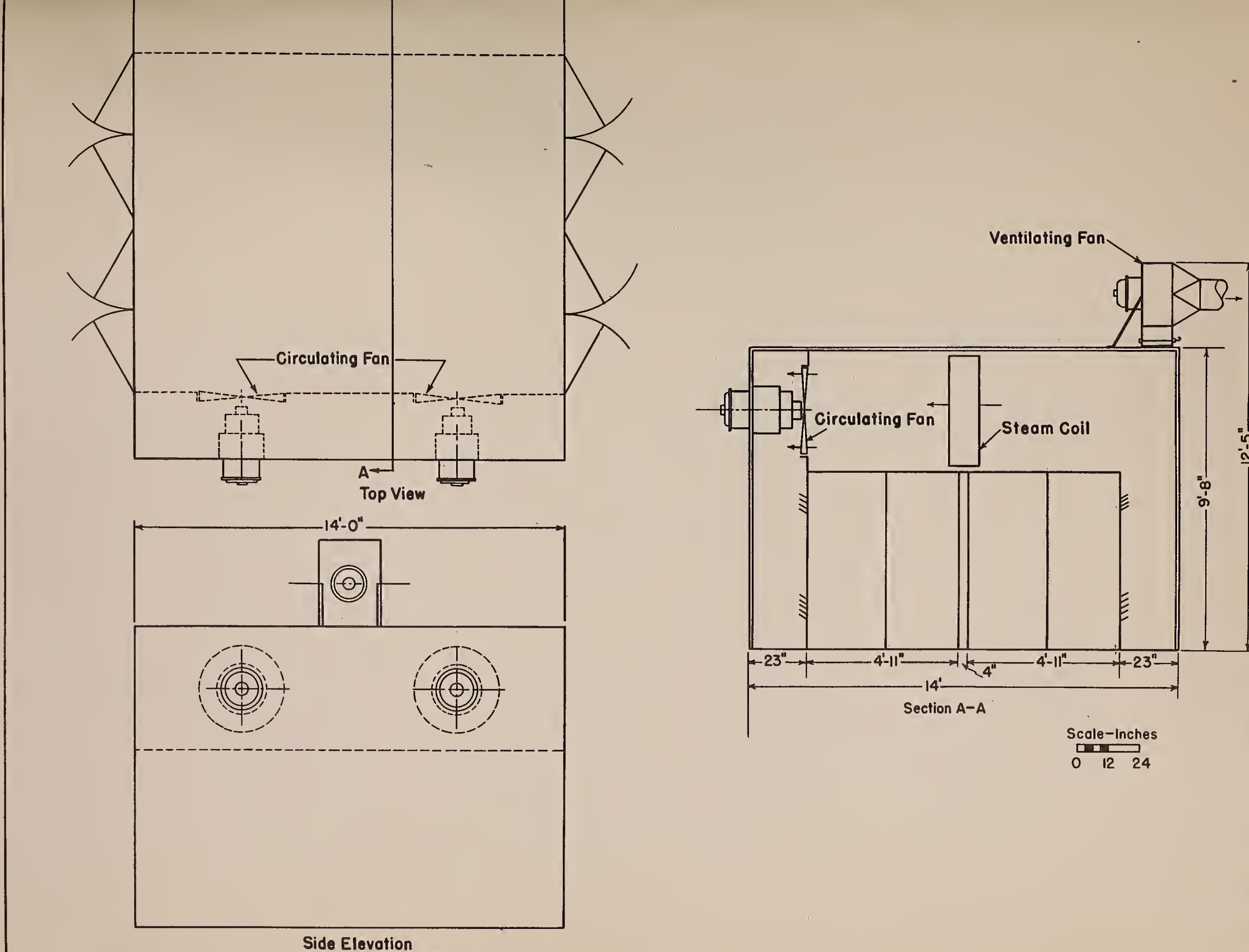


Figure 15. —Tunnel drier

the gloves and the container used for the caustic thoroughly with water after each use. If caustic gets on the hands, apply vinegar or wash them thoroughly in water. Lime also has a caustic action and should be washed from the hands at once.

ACID FOR NEUTRALIZING STOCK

Sulfuric acid, technical grade, 93-percent strength, is purchased in 200-pound glass carboys. *Sulfuric acid is a very dangerous chemical and must be handled with extreme care.* Any acid spilled on the clothes or hands must be washed off immediately with large volumes of fresh water, and the places touched by the acid should be treated with a solution of baking soda (1 tablespoonful per pint of water). A gallon bottle of the soda solution should be available at all times. The concentrated acid will char cloth or leather, and even the diluted acid will damage leather shoes and eat holes in cotton clothing. Rubber shoes and gloves are not much affected if rinsed immediately after contact with the acid.

Concentrated sulfuric acid is handled in lead or stoneware vessels. Acid is removed from the carboy by means of a plastic syphon or pump. To make a 20-percent sulfuric acid solution, first place 12 gallons of tap water in a 15-gallon stoneware jar, and then weigh out 27 pounds of acid in a 3-gallon lead bucket and pour the acid very slowly into the water in the crock while stirring with a glass or wooden rod. Use rubber gloves and protect the eyes with goggles. A reaction producing much heat occurs when concentrated sulfuric acid and water are mixed. Therefore, the acid must be added slowly to the water so that the jar will not heat too rapidly and crack. *Never pour water into the strong acid.*

When neutralizing the water in the stock tank to pH 6.0, about 32 pounds or 4 gallons of 20-percent sulfuric acid will be required, the exact quantity depending on the alkalinity of the water. After the plant is operated for a time, it will be known how much acid can be added to each tank without necessitating much adjustment. In the beginning the acid should be transferred slowly from the 3-gallon lead bucket to the tank with a porcelain casserole used as a dipper, while frequent pH tests are made with suitable indicator paper. Two 15-gallon stoneware jars with covers should be provided for sulfuric acid preparation and storage. The covers should be kept on the jars at all times, and the jars should be marked "Dangerous Chemical."

ROSIN SIZE SOLUTION

A 55-gallon glycerin drum, without top and fitted with a 1/8" iron drain pipe that has two branches with two brass globe valves to deliver into two tanks, is placed on the second floor near the stock tanks. Fifty gallons of tap water is run into the drum and is heated with steam from a rubber garden hose attached to a steam line. Twenty-three pounds twelve ounces of dry rosin size (purchased in 100-pound paper bags) is weighed out and added to the hot water. The mixture is stirred with a stick to insure all of the size being wetted. Solution takes about 15 minutes. All of this solution is run into the proper stock tank when the size is to be added.

ALUM SOLUTION

A 55-gallon wooden barrel, fitted with 1/8" drain pipe and valves similar to those described for the rosin size solution, is used for making up and delivering each batch of alum. This is also placed on the second floor near the stock tanks. Fifty gallons of tap water is placed in the barrel and the water is heated with the steam

hose. Next, 60 pounds 2 ounces of alum (aluminum sulfate, purchased in 100-pounds paper bags) is weighed out and stirred into the hot water. Solution takes about 15 minutes. If the pH is greater than 5.2, about 1 pound more of alum, dissolved in water is added. The alum solution has an acid reaction that will sooner or later destroy the pipe which, however, is easily replaced.

ASPHALT EMULSION

By making up the asphalt emulsion in a 50-gallon glycerin drum, a supply for 2 days' production is provided. Forty-five gallons of tap water is placed in the drum and 109 pounds of the stiff emulsion (approximately 72 percent solids) is weighed into it. It is stirred with an electric stirrer for about 10 minutes. Twenty-five gallons of this solution is sufficient to coat 4,500 square feet of board.

ADJUSTING THE CONSISTENCY TO 2 PERCENT

The number of gallons of liquid in any of the three large tanks (12' high, 13' diameter) may be determined by gaging with a calibrated pole having a 1" x 2" cross section and marked at every inch. Each inch in depth is equivalent to 78.5 gallons based on capacity of the tank. Assuming a 64-percent yield of pulp, the final volume of the liquid in the tank at exactly 2-percent consistency will be 9,400 gallons, or a depth of 120 inches on the pole.

At the time the consistency sample is taken, the depth of the liquid is measured to the nearest half-inch. The consistency determination is made as described under Testing Methods, page 29. The consistency will always be found to be slightly greater than 2 percent, probably between 2.1 and 2.2 percent. The number of inches of water to be added to the stock tank to bring the stock to 2 percent can be calculated as follows:

$$\frac{\text{Consistency found x inches in tank}}{2} = \text{Total inches of liquid required in tank to produce 2-percent consistency}$$

For example, the consistency is found to be 2.2 percent and the depth 100 inches: $\frac{2.2 \times 100}{2} = 110$ inches. Therefore 10 inches of water must be added.

To convert inches in tank to gallons, multiply by 78.5.
To convert gallons to pounds of water, multiply by 8.33.

GENERAL SAFETY

All pulleys, cogwheels, and belts should be enclosed with guards to prevent injury to clothing, hands, arms, or feet.

Water and steam pipes should be grounded to prevent the carrying of stray electric currents. Steam pipes should be covered with a heat-insulating material to prevent burns.

Baling wire should be carefully picked up and removed to safe storage or disposal. Scratches or skin punctures from wire should be treated immediately with antiseptic solution and watched.

A first-aid kit should be provided, and at least one operator per shift should be qualified as a first-aid man.

Eye injuries, cuts, or any other serious injuries should receive immediate attention from a qualified practicing physician.

TESTING METHODS

The testing methods required for control purposes in the laboratory and pilot-plant investigations and applicable for plant control work are described below.

CONSISTENCY DETERMINATION

The percentage of dry fiber in a water suspension of pulp is known in the paper and fiber board industry as the consistency of the stock. The apparatus used in making this determination includes an 8-ounce jelly glass, the capacity of which to the top rim is accurately determined in milliliters; a thin (1/32") metal plate, about 3 1/4 inches square, having perfectly plane surfaces (the metal plate when placed on top of the jelly glass must make a tight seal); a Buchner funnel and filtering flask; hardened filter papers to fit the Buchner funnel; a pulp balance weighing to 0.01 gram; and a drying oven.

The most difficult feature of the consistency determination is obtaining a representative sample of the fiber suspension. While the fiber suspension to be sampled is briskly agitated, the empty glass with the plate firmly held over the mouth is introduced by hand about 12 inches below the surface of the suspension, the mouth of the glass facing the on-coming stream of pulp. The plate is then quickly removed so that the glass fills; the glass is moved so that its top is in a horizontal position; the plate is slid over the top of the glass; and the filled and covered glass is carefully removed from the fiber suspension. Any fibers adhering to the outside of the container and cover are removed, care being taken not to lose any of the contents of the glass proper. All of the fiber suspension is then filtered on a weighed, hardened filter paper under vacuum. Any fibers adhering to the glass or the metal plate are washed into the funnel. The filter paper and pad of pulp are dried and weighed to constant weight in grams at about 220° F. The consistency is then computed as follows:

$$\frac{\text{Grams of dry pulp and paper} - \text{grams of paper} \times 100}{\text{Capacity of glass in milliliters}} = \text{Percent consistency}$$

Some practice is required to obtain duplicate results.

FREENESS

Freeness is a term used in the paper and fiber board industry to express the relative ease with which water drains from a pulp suspension or, inversely, the relative water-holding capacity of the pulp. A suspension of fine fibers has lower freeness or greater water-holding capacity than a suspension of coarser fibers because of the greater surface area of the fine fibers. Also, fibers which are swollen by mechanical treatment in water hold more water than unswollen fibers. The drainage rate of pulp suspensions on the board-forming machine is a measure of freeness.

DETERMINATION OF pH OF SOLUTIONS

This method determines the degree of acidity or alkalinity in water solution. The pH scale ranges from 0.0 to 14.0; as the pH increases from 0.0 to 6.9 the acidity decreases; pH 7.0 represents neutrality; and as the pH increases from 7.1 to 14.0 the alkalinity increases.

The use of specially prepared indicator test papers, sold by chemical supply companies, provides a simple means of determining the pH value of water and stock suspensions. Most natural waters are alkaline in reaction. Papermakers' alum (crystalline aluminum sulfate) is used to precipitate the rosin from sizing solution onto the fiber, but much of it could be used up in neutralizing the alkalinity of fresh water added to the stock. Sulfuric acid is a much cheaper neutralizing agent, and its use for adjusting pH saves considerable amounts of alum. Moreover, by neutralizing the stock suspension prepared from the washed stock with sulfuric acid to a definite pH of 6.0, it is possible to use exactly the same amount of alum for sizing each batch of stock, providing the same amount of rosin size is used each time. The following range of test papers should be available:

	Test paper number[1]					
	60	70	80	90	110	120
pH range	2.7-4.7	3.9-5.4	5.0-6.6	5.2-6.9	6.1-7.4	6.9-8.4

[1] According to system used by one chemical supply company.

The pH value of the solution is determined by placing a drop of the solution to be tested on a small strip of the paper. The change in color of the paper may then be matched with standard printed colors on the glass bottle. If no change in color of the strip takes place or if the color change is at either end of the range of the paper, another fractional range test paper should be used. For example, if a strip of No. 80 paper shows a reading of pH 5.0, a check should be made with No. 70 paper; or if No. 80 paper shows a pH of 6.6, a check should be made with No. 90 paper.

In the sizing operation, a pH of 4.7 to 5.2 should result after the alum is added and the mixture is well stirred. If the pH is 4.6 or less, too much alum has been added and the alum should be decreased on the next batch. If the pH is 5.3 or more, add alum in small quantities until a pH of 5.2 to 4.7 is attained.

METHOD FOR DETERMINING FINE FIBER

The apparatus consists of a 28-quart dishpan (22" diameter x 6.5" deep) and an easily constructed rocking screen shown in figures 16 and 17. In making the test, 50 grams of pulp leaving the washer is weighed out and well mixed by stirring in 2 gallons of water in a bucket for 5 minutes. Nine quarts of water is placed in the dishpan containing the screen rocker, and the pulp suspension is carefully poured into the rocker which is rocked 20 to 25 times per minute. The fines pass out through the screen. At the end of 6 minutes the rocker is removed and the water in the pan is filtered through a weighed filter paper. The fines and paper are then dried in an oven for 2 hours to constant weight. The percentage of fines is calculated as follows:

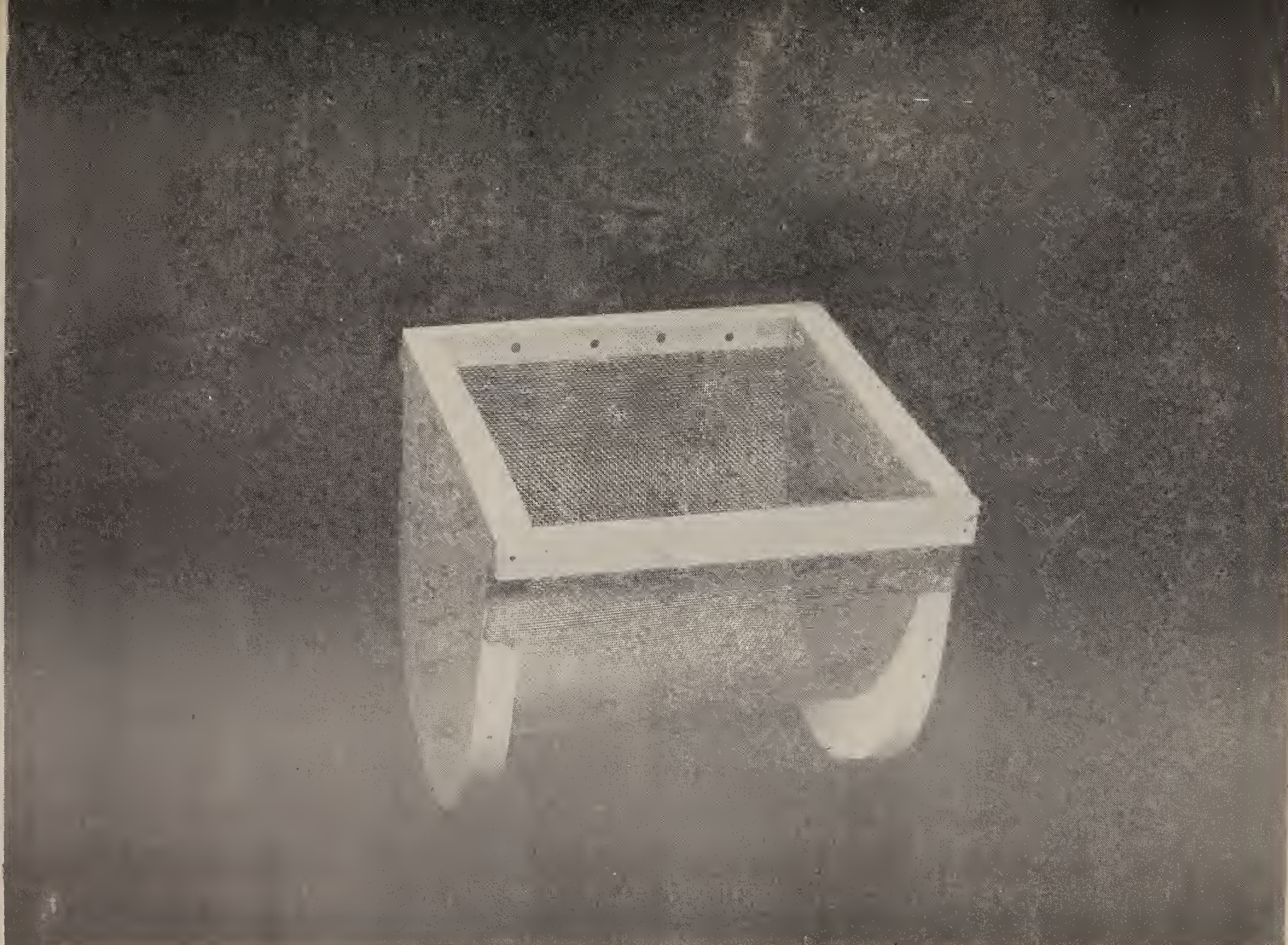


Figure 16. —Rocker screen.

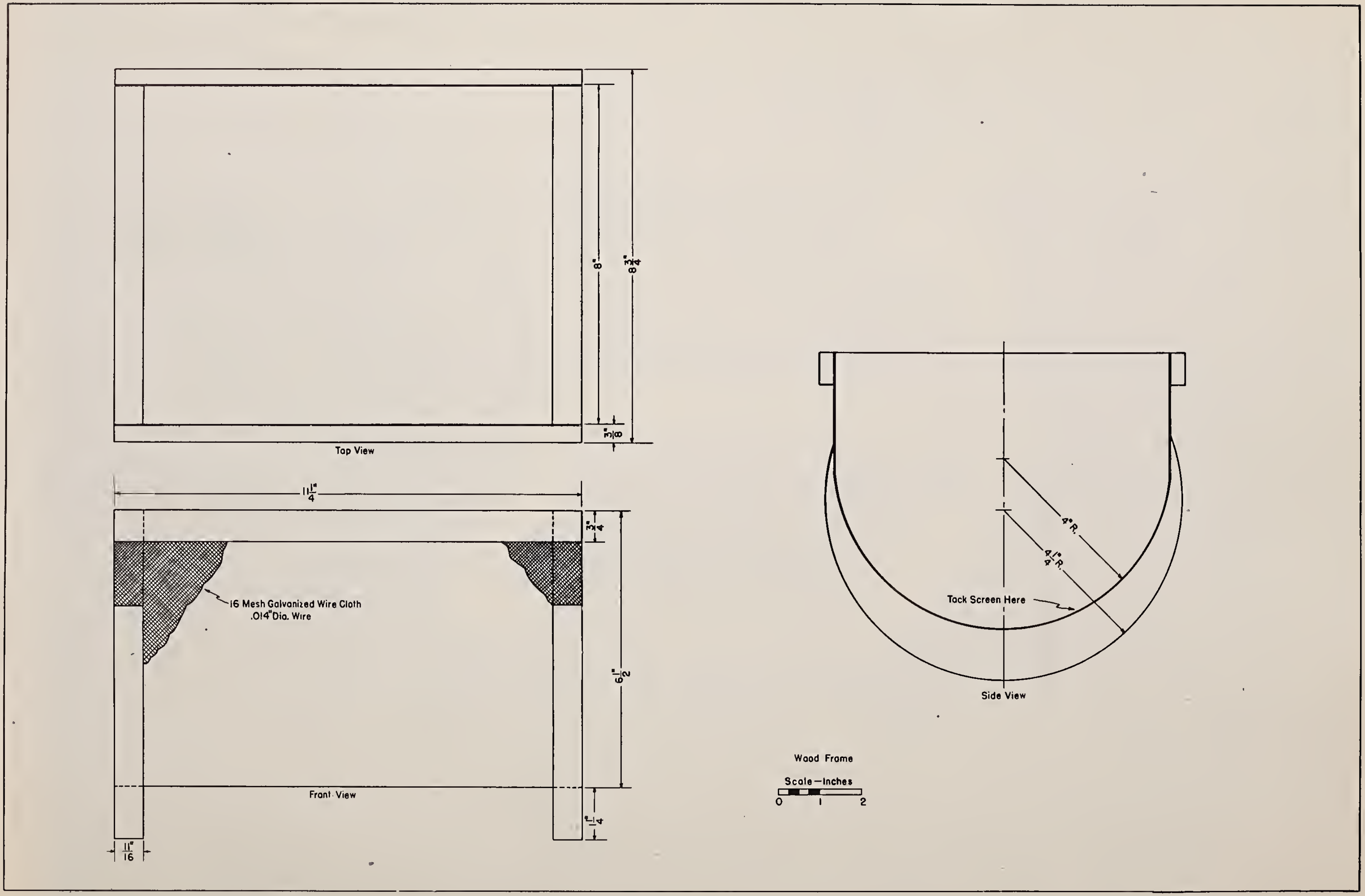


Figure 17.—Design of rocker screen shown in figure 16.

$$\text{Percentage of fines} = \frac{\text{Weight of paper and fines} - \text{weight of paper} \times 100}{\text{Dry weight of original pulp}}$$

The dry weight of the original pulp is obtained by drying a weighed sample of pulp taken from the washer at the same time the test sample is obtained.

LABOR AND OPERATING DUTIES SCHEDULE

The permanent operating personnel consists of a manager, three foremen, three board-machine operators, three handy men, one laborer, and one or more salesmen (on commission), based on operation of plant 24 hours a day in three shifts.

The manager has charge of production and sales as well as purchase of straw, chemicals, other supplies, and machinery. He must be capable of making or directing repairs or maintaining and operating the plant. It will be his duty to supervise the whole operation and to assist in operating when breakdowns or other operating bottlenecks occur.

The foreman will be responsible for the operation of the boiler which is fully automatic but must be checked frequently. He will also be responsible for the operation of the cooker and the drier after they have been loaded. The cooker operation is started 6 hours before the end of the shift and the drier operation at the beginning of the shift. The foreman will prepare all of the chemicals, add chemicals to the cooker and acid, size, and alum to the stock tanks, determine pH and consistency, and make final adjustments to prepare 2-percent-consistency fiber suspensions. He will operate the conveyor, shredder, and washer; adjust water valves during the shredding operation; and assist in spraying and piling finished boards.

The board-machine man will operate the board machine and the press.

The handy man will load and unload the drier, spray the boards with asphalt and pile them. Every hour he must supply the board machine with a skid load of 24 empty racks and remove a skid load of boards from the press. He must chop straw to load the cooker, assist in wet shredding, and relieve the board-machine operator for lunch.

The laborer will work only on the daylight shift and be responsible for transporting about 105 bales of straw from the stack into the plant. The 1.5-ton truck provided will hold at least 16 bales per trip. This will leave about 2 1/2 hours for sweeping and cleaning the plant.

Table 9 shows in detail the duties of each of the operating personnel, together with the time allotted to carrying out each of the duties assigned. Table 10 shows the operating schedule for the foreman and handy man on one shift, the board-machine operator's and laborer's duties being as just described.

ESTIMATED EQUIPMENT REQUIREMENTS AND COSTS

The equipment estimates given below are as complete as can be made without a knowledge of the actual building and plant layout to be used. They do not include the number of feet of pipe and wire required, the length of the conveyor, and similar details. Equipment to be built is shown in figures 1, 2, 4, 5, 7, 11, 13, 14, and 16. Equipment to be purchased is described in some detail.

TABLE 9.--*Distribution of duties*

First (day) shift		Second shift	Third shift
Laborer (reports for day work only)			
Supplies straw for 24-hour operation	5.0 hours		
Cleans floors	2-1/2 hours		
Lunch	1/2 hour		
Foreman			
Supervises operation of boiler, cooker, and drier	7-1/2 hours	Same	Same
Operates wet shredder		Same	Same
Prepares chemicals for operation		Same	Same
Controls sizing and consistency of pulp; assists in spraying and piling board		Same	Same
Lunch	1/2 hour	Same	Same
Board-machine Operator			
Board formation	7-1/2 hour	Same	Same
Lunch	1/2 hour	Same	Same
Handy Man			
Unload and load drier	40 minutes	Same	Same
Transferring racks	45 minutes	Same	Same
Relief board operator	30 minutes	Same	Same
Spraying boards	190 minutes	Same	Same
Loading cooker	85 minutes	Same	Same
Shredding	60 minutes	Same	Same
Lunch	30 minutes	Same	Same

Note: Drier will operate first and second shifts and be shut down third shift. Handy man and foreman will work at repairs and complete odd jobs during drier shut-down.

Table 10.--Labor schedule for daylight shift

Clock time	Foreman	Handy man
8:00-8:15	Weigh cooking chemicals	Unload drier
8:15-8:30	Hydrate lime	Unload and load drier
8:30-8:45	Prepare chemicals for cooker	Load and start drier
8:45-9:00	Discharge cooker; start shredding	Aid in shredding
9:00-9:15	Discharge cooker; continue shredding	Ditto
9:15-9:30	Continue shredding	Chop straw; fill cooker
9:30-9:45	Ditto	Pump chemicals to cooker
9:45-10:00	Ditto	Close cooker
10:00-10:15	Ditto	Start cooker; hold at 252° F. to wilt straw
10:15-10:30	Ditto	Continue wilt; aid in shredding
10:30-10:45	Complete shredding	Ditto
10:45-11:00	Start stock pump; add acid to pulp in chest; take and filter stock sample	Exhaust cooker
11:00-11:15	Weigh rosin and alum	Exhaust cooker; prepare asphalt
11:15-11:30	Dissolve sizing chemicals	Open cooker
11:30-11:45	Lunch	Chop straw; close cooker
11:45-12:00	Lunch	Start final cook
12:00-12:15	Test pH; add rosin; continue cook	Lunch
12:15-12:30	Continue cook	Lunch
12:30-12:45	Test pH; add alum; continue cook	Relieve board-machine man
12:45-1:00	Weigh pulp from stock sample; test pH; continue cook	Ditto
1:00-1:15	Adjust level in chest; take and filter stock sample; continue cook	Spray and pile boards
1:15-1:30	Spray and pile boards; continue cook	Ditto
1:30-1:45	Ditto	Ditto
1:45-2:00	Ditto	Ditto
2:00-2:15	Ditto	Ditto
2:15-2:30	Ditto	Ditto
2:30-2:45	Spray and pile boards; exhaust cooker	Ditto
2:45-3:00	Ditto	Ditto
3:00-3:15	Ditto	Ditto
3:15-3:30	Weigh pulp from stock sample; exhaust cooker	Ditto
3:30-3:45	Spray and pile boards; exhaust cooker	Ditto
3:45-4:00	Spray and pile boards	Open cooker

Note: The foreman or handy man will check the boiler and drier once every hour.

The cost estimates, particularly as regards labor and straw, may be out of line because they were obtained for the most part, prior to August, 1945. Anyone undertaking to build a plant would be obliged to bring the estimates up to date by contacting reputable suppliers.

ESTIMATED COST OF PLANT EQUIPMENT TO BE PURCHASED[2]

	Approximate Cost
1. Boiler and accessories:	
Boiler, 87 hp., horizontal, fire tube, 100 p.s.i. gage pressure	$ 2,030.00
Smoke stack, 26" diameter, 60' high, No. 10-gage black steel	265.00
Oil burner, 103 hp., with automatic accessories	576.00
Oil tank and accessories, 2,000 gallons, 64" diameter 12' long	200.00
Boiler return system; 20 gallons per minute at 100 p.s.i.	479.00
Transportation	75.00
Erection	300.00
Insulation	500.00
Total	$ 4,425.00
2. Water softener, zeolite, 10 gallons per minute	$ 325.00
3. Cooker, single shell, globe, rotary, 9' diameter complete with 7 1/2 hp. splashproof motor and starting equipment	$ 6,000.00
Transportation	500.00
Erection	1,000.00
Total	$ 7,500.00
4. Storage tanks and accessories:	
Three hemlock storage tanks, 11,000-gallon capacity, 13' diameter, 12' high (outside dimensions)	$ 930.00
Two agitators, with two-arm stirrer, 10 hp. motor, and starting equipment	840.00
Transportation	100.00
Erection	200.00
One galvanized 18-gage steel tank for chemical make-up, 5' diameter, 4' 8" high, with an opening for a 2" iron pipe at the center of the bottom	65.00
One galvanized 20-gage steel shredder mixing tank, 5' diameter, 4' high with an opening for a 3" iron pipe at the side as near the bottom as is mechanically possible	50.00
Total	$ 2,185.00
5. Dry-straw cutter:	
Roughage mill, 18" cutter head (equal to No. 4-A Bear Cat Mill of Western Land Roller Company)	$ 500.00
Motor, 10 hp., 3,600 r.p.m. with starting equipment	200.00
Total	$ 700.00

[2] Several items listed in these estimates were of special design, and mention of the names of manufacturers does not imply that the same equipment made by others would be less suitable.

	Approximate Cost
6. Wet-pulp shredder:	
Hammer mill, 30" x 24"	$ 1,385.00
Splashproof motor, 40 hp., with accessories	800.00
Transportation	50.00
Erection foundation	50.00
Total	$ 2,235.00
7. Drag elevator (less spouts, derrick and feed hopper) with 2 hp. splashproof motor	$ 200.00
8. Press, 30-ton, with 5 hp. motor and pump connected to cylinder by flexible high-pressure hose (equal to that of Rodgers Hydraulic Inc., Minneapolis, Minn.). Press to be supplied complete with table tolls on bottom platen and mechanism on top platen for confining edges during pressing.	$ 2,300.00
9. Transfer trolley or electric hoist, 500-pound capacity, 1/2 hp. motor	$ 319.00
10. Asphalt-spray equipment, portable, 1-hp. capacity	$ 220.00
11. Skid lift truck and skids:	
Truck, hand, 2,500-pound capacity	$ 172.00
Twenty skids for 4' x 4' boards; 3,500-pound capacity	144.00
Total	$ 316.00
12. Drier, 2-unit, truck, 14' x 14' x 10' (equal to that of Proctor and Schwartz Inc.)	$ 6,430.00
Transportation	90.00
Erection	100.00
Total	$ 6,620.00
13. Three pulp or trash pumps with 1 hp. motors, 150-gallons-per-minute delivery, 3" inlet and 3" outlet (equal to Fairbanks-Morse pump). Two are for stock chests and the other for delivering pulp from the shredder pit to the rotary washer.	$ 500.00
14. Two centrifugal water pumps, 210-gallons-per-minute delivery, direct drive, standard fitted with 3" suction and 2-1/2" discharge, supplied with a splashproof 3 hp., 1,750 r.p.m. motor and necessary starting equipment. One is for the white water tank and the other for the rotary washer.	$ 320.00

	Approximate Cost
15. One centrifugal water pump for chemical make-up tank, 110-gallons-per-minute delivery, direct drive, standard fitted with 2" suction and discharge, supplied with a splashproof 1 1/2 hp., 1,750 r.p.m. motor and necessary starting equipment	$ 122.00
16. One centrifugal water pump for pumping white water from board-forming machine and press, 45-gallons-per-minute delivery, direct drive, standard fitted with 1 1/2" suction and discharge, supplied with splashproof 1/2 hp., 1,750 r.p.m. motor and necessary starting equipment	$ 70.00
17. One centrifugal water pump for the rotary washer, 20-gallons-per-minute delivery, direct drive, standard fitted with 1" suction and discharge, with splashproof 1/4 hp., 1,750 r.p.m. motor	$ 45.00
18. Three electric stirrers, 1/2 hp., 1,800 r.p.m. Two are for the two metering head boxes and the other for the shredder mixing tank.	$ 450.00
19. Three electric stirrers, 1/4 hp., 1,800 r.p.m. One is for the chemical make-up tank, one for the preparation of alum and rosin, and the third for the preparation of asphalt emulsion.	$ 240.00
20. Drag elevator with attachment for elevating straw (less spouts and feed hopper) with 3 hp. gasoline motor	$ 400.00
21. Truck, 1.5 ton	$ 1,200.00
22. Platform counter scale, 75-pound capacity in 1-ounce divisions	$ 34.00
23. Platform scale on wheels, 500-pound capacity	$ 29.00
24. One horizontal ratiomotor for driving the rotary washer, 1 hp., 143 r.p.m. with torque of 395 inch-pounds, supplied with necessary starting equipment	$ 120.00
25. One horizontal ratiomotor for driving the paddle wheel in the shredder metering box, 1/4 hp., 36 r.p.m. with torque of 230 inch-pounds	$ 50.00
26. One hoist, 1/4-ton with 12' lift	$ 80.00
27. Table rolls, three sections, 5' long	$ 100.00
Total estimated cost of plant equipment to be purchased	$31,105.00

ESTIMATED COST OF CHEMICAL MAKE-UP AND CONTROL EQUIPMENT TO BE PURCHASED

1. Two 15-gallon stoneware jars with covers	$ 6.00
2. Lead-lined pail, 3-gallon capacity	12.00

		Approximate Cost
3.	Two casseroles, porcelain, 750-ml. capacity	$ 3.50
4.	Filter pump, brass, threaded for attachment to 1/4-inch or 3/8-inch iron pipe	1.25
5.	Filtering flask, 500-ml. capacity	.95
6.	Buchner-type funnel, porcelain, with perforated plate 126 mm. in diameter	4.00
7.	Six packages of hardened filter paper, 12-1/2 cm.diameter	12.30
8.	Six jelly glasses, 3-1/2" high with inside diameter of 2-1/2" at the top and of about 1-3/4" at the bottom	.60
9.	Quick-drying electric oven, 110 volt, 60 cycle, single phase, AC	70.00
10.	Thermometer, Fahrenheit, 30° to 300°	1.25
11.	Four feet of heavy-walled black rubber tubing for vacuum filtration, inside diameter 5/16"	1.20
12.	Rubber stoppers, one hole, one each of sizes 3, 4, 5, 6, and 7	.60
13.	Balance, general laboratory, for weighing pulp	43.00
14.	Two balance riders, aluminum, each weighing 10 milligrams	.50
15.	Set of balance weights, 10 milligram to 200 gram	6.00
16.	Four glass pie plates of approximately 10-1/2" outside diameter and 1 1/2" deep	.80
17.	Syphon for removing acid from carboy, plastic	8.00
18.	Two electric clocks and timers	16.20
19.	Indicator paper for pH determinations, 3 vials of strips for each of six divisions in the range from 2.7 to 8.4	11.70
20.	Rubber gloves, two pairs of No. 10-1/2 and two pairs of No. 11	16.00
21.	Rubber apron, 46" long	1.50
22.	Three pairs of goggles	6.00
23.	Two respirators	4.00
24.	First-aid kit	8.00

		Approximate Cost
25.	One package of small individually wrapped bandages for minor injuries	$ 1.00
26.	Rubber boots, one pair size 9 and one pair size 11	10.00
27.	One pair of asbestos gloves	3.60
28.	Dishpan, aluminum or enamel-lined, 22" diameter, 6-1/2" high, 28-quart capacity	4.00
	Total estimated cost of chemical make-up and control equipment to be purchased	$ 254.00

ESTIMATED COST OF MISCELLANEOUS EQUIPMENT TO BE PURCHASED

1.	Cleaning equipment	$ 20.00
2.	Miscellaneous tools	50.00
3.	Two carbon dioxide fire extinguishers, capacity of each 10 pounds	84.00
4.	Reducing valve, 100 to 50 pounds, steam	50.00
5.	Water hose and fittings	15.00
6.	Two secondhand glycerin drums, 55-gallon capacity	6.00
7.	Secondhand wooden barrel, 55-gallon capacity	2.00
8.	Mortar-mixing hoe with two holes and box	7.50
9.	Two scoops, 12" x 13"	5.50
10.	Two 4-tine manure forks	2.90
11.	Office equipment:	
	Standard typewriter, desk, desk chair, filing cabinet, and several straight-back chairs	200.00
12.	Miscellaneous piping, fittings, wire, electric fixtures, etc.	1,000.00
	Total estimated cost of miscellaneous equipment to be purchased	$1,443.00

ESTIMATED COST OF EQUIPMENT TO BE CONSTRUCTED

1.	Shredder metering box (fig. 1)	$ 100.00
2.	Rotary washer (fig. 2)	300.00

	Approximate Cost
3. Two metering head boxes (fig. 13)	$ 200.00
4. Board forming machine (fig. 6)	1,000.00
5. Wire screen trays (fig. 14), 480 at $7.40 each	3,552.00
Total estimated cost of equipment to be constructed	$ 5,152.00

ESTIMATED COSTS OF LAND AND BUILDING

The cost of land (2 acres) in a small town in a rural area is estimated at $2,000, and the cost of a two-story frame building complying with the plans shown in figure 9 and having 5,240 square feet of floor space is estimated at $10,000.

CAPITAL REQUIRED

According to the preceding estimates about $38,000 would be required for equipment and $12,000 for land and building, making a total capital investment in plant of $50,000. In addition, a working capital of $12,000 would be required for straw, chemicals, fuel, water, electricity, labor and management until the plant becomes self-sustaining and profitable.

ESTIMATED COSTS OF MANUFACTURE

The estimates given in table 11 are based for the most part on quotations obtained during the recent war period. Costs will vary with location of the plant and market conditions. However, by amending the cost factors, clearly shown in table 11, it will be easy to re-estimate costs. It is very necessary for anyone who considers undertaking this rural process to re-estimate costs completely, based on local conditions and on up-to-date quotations on raw materials, equipment, buildings, and wages.

Under the conditions existing in the summer of 1945 it was estimated that in a favorably located plant the direct manufacturing expense would be $27.21 per 1,000 square feet of board. The fixed charges per 1,000 square feet of board were estimated at $6.66 which, together with $27.21 direct manufacturing expense, gives a total manufacturing cost of $33.87. This cost is approximately double that of mass-production manufacture because of the high labor costs and the small production per unit of labor. If buildings are available locally or some of the equipment can be obtained as secondhand or from war industry surpluses, the capital investment may be lowered, with consequent lowering of fixed charges.

It is evident that idleness due to any cause would seriously affect costs and profits. Fixed charges, including the salary of the manager, amount to $1,000 per month.

SELLING AND SALES PRICES

At present, 25/32" insulating sheathing board is merchandized in two ways. The main channel is through lumber dealers and building-material supply organizations who purchase at dealer prices from the large manufacturers. The dealer price includes freight to dealers' yards, together with a very considerable amount of merchandising

and advertising help supplied by the manufacturer. The second channel of distribution to the contractor and retail trade is through mail-order houses that sell the product at $50 per thousand square feet, f.o.b. plant in Iowa on the Mississippi River. Sales prices by lumber or building supply dealers vary from about $65 per thousand for small retail purchases to somewhat more than $50 to large contractors carrying on extensive building projects.

Fifty dollars per thousand is, therefore, the top price at which the product of the rural industry may be expected to sell. Although the product can be made to meet fully the strength and insulation values of standard board, it cannot be expected to be either quite as uniform in quality or as attractive in appearance as that of the large manufacturers, and it would not be wrapped in bundles. It is doubtful, therefore, whether the product could command a price of $50 per thousand.

Due to the high manufacturing cost and small profit margin at a sales price of $50 or somewhat less, no room is left for a jobber's or dealer's profit; hence sales must be made directly to the user, f.o.b. plant. In localities where higher prices may still be competitive, jobber distribution is conceivable.

It is not planned to package the board, since it can be easily piled into ordinary farm trucks. This eliminates packaging expense.

A certain proportion of the production will be found to be substandard for one reason or another. That this substandard board must be kept to an absolute minimum is obvious. Substandard board may be used in many places in farm buildings and it is thought that the bare costs of such board may be obtained.

It is difficult to estimate selling costs without knowledge of the local conditions to be met. For example, selling through a cooperative would probably be less costly than selling on commission. For purposes of estimating sales costs it is assumed that one or more salesmen will work on a commission of $2 per thousand square feet and a traveling expense of $1.

Some advertising literature will have to be provided, and local newspaper advertising will be desirable. For this purpose $0.25 per thousand square feet is provided in the estimates shown in table 11.

It is evident that carelessness in manufacture, lack of sales ability, and poor business management will affect profits quickly and seriously.

The whole matter of sales costs and markets requires the most careful study before making any investment.

ESTIMATES OF INCOME

Based on data in table 11, an estimate of income on invested capital when the board is sold at different price levels is presented in table 12.

It is evident that this industry will succeed only under favorable circumstances of location and under good management.

The location of the plant is of major importance. If it is assumed that 3,000 square feet of board will be used in the average building, then 300 to 400 sales per

year will be required to move the annual production of the plant. The trading area in which the plant is located must, therefore, be such that for a period of a least 10 years, during which the plant is amortized, 3,000 to 4,000 structures using approximately 3,000 square feet each will be built or remodeled. The radius and character of the trading area must be such that transportation costs are low so that the purchasers will be willing to take delivery of the board at the plant. Selling outside of the local area will involve more competitive merchandising with lower profits.

The plant must be located in an area where farmers will be willing to contract to collect, bale, deliver, and pile 1,100 tons of straw annually at the plant site. Contracts should be made directly with farmers so as to insure maximum profit to them for the straw and for their labor. The hauling radius from the plant should be less than 10 miles and preferably 5 miles so as to reduce hauling costs.

The plant should be located in a small community where it becomes an important business, and where at the same time living costs are relatively low. This community should be located on the edge of the main trading center, on a main highway, and preferably on a railroad.

Business management will be the controlling factor in the success of the operation. There is no exception to this in either large or small business, but the small business cannot generally weather strikes, business depressions, and the like as easily as large business.

Taking these requirements into account it is evident that a thorough study and survey is most necessary before coming to a conclusion as to the advisability of undertaking the establishment of this rural industry. Localities can probably be found where the business will succeed in a healthy fashion. Management by a successful farm cooperative in the right locality would appear logical. Under less than ideal conditions as to markets, costs, and business management, the venture is likely to fail or to be of a marginal character. The process is one suited to islands or foreign countries where labor costs are low, transportation costs are high, and where insulating building materials are not manufactured on a large scale.

TABLE 11.--*Estimated cost of production of 25/32-inch insulating board from wheat straw*

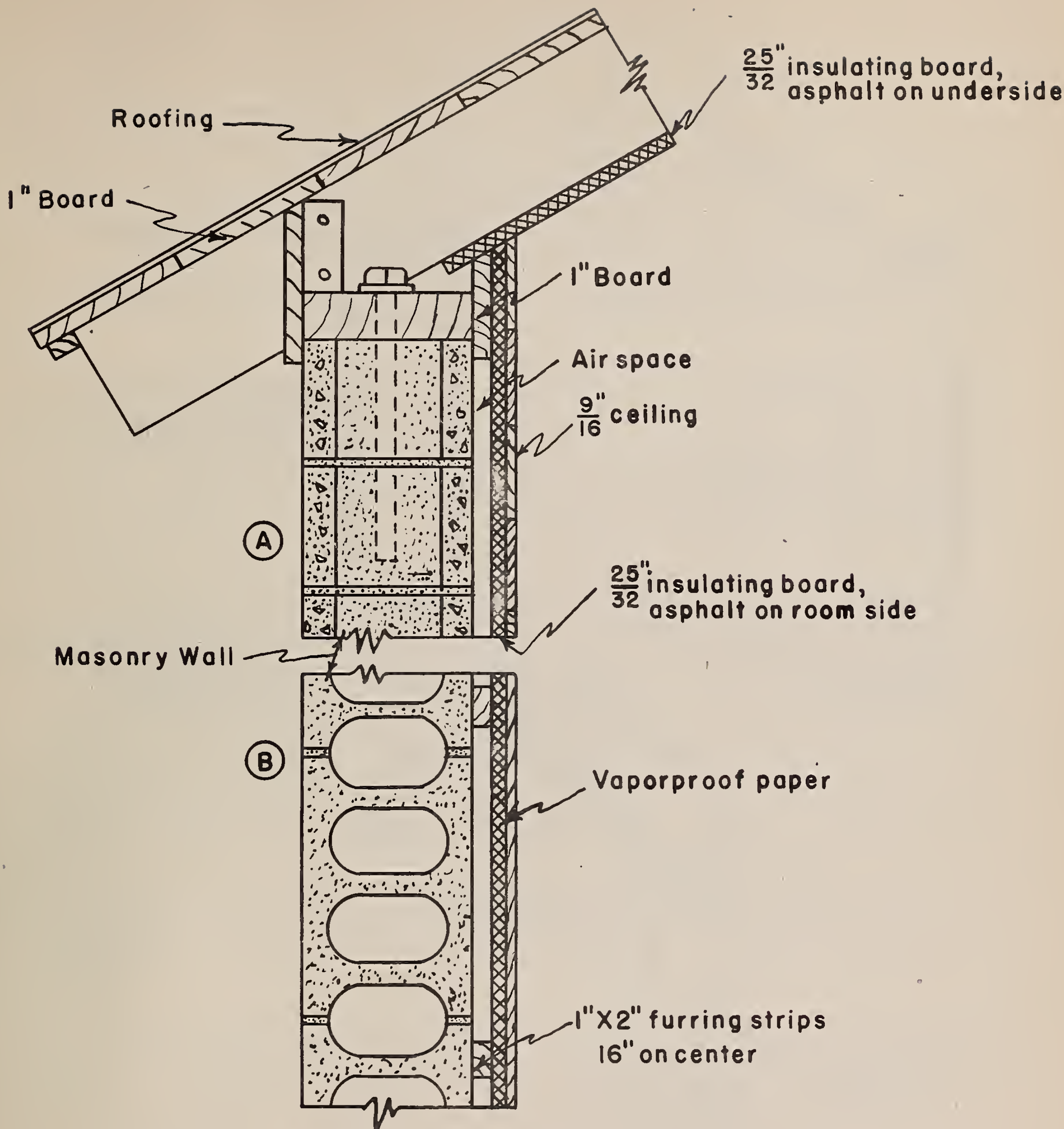
Item	Unit cost	Per 1,000 square feet		Per month of 25 days (112,500 sq. ft. production)		Per year of 300 days (1,350,000 sq. ft. production)	
		Amount used	Cost	Amount used	Cost	Amount used	Cost
Materials:		Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Wheat straw	$5 per ton	1,640.0	4.10	184,500	461.25	2,214,000	5,535
Burned lime, CaO[1]	$10 per ton	62.7	.31	7,054	35.27	84,645	423
Flake caustic, NaOH[1]	$3 per hundredweight	3.5	.11	394	11.82	4,725	142
Dry rosin size, XXX	$4.75 per hundredweight	15.8	.75	1,778	84.46	21,330	1,013
Alum, $Al_2(SO_4)_3\ 18\ H_2O$ [1]	$1.40 per hundredweight	40.1	.56	4,511	63.15	54,135	758
Sulfuric acid, technical [1]	$16.50 per ton	6.0	.05	675	5.57	8,100	67
Emulsified asphalt	$0.04 per pound	13.2	.53	1,485	59.40	17,820	713
Sodium chloride [1]	$15.70 per ton	13.3	.10	1,496	11.74	17,955	141
Total			6.51		732.66		8,792
Water, steam, and electricity:							
Water	$0.05 per 1,000 gallon	[2]7,294.0	.36	[2]820,575	41.03	[2]9,846,900	492
Steam for cooking	$0.40 per 1,000 pound	2,082.0	.83	234,225	93.69	2,810,700	1,124
Steam for drying	$0.40 per 1,000 pound	6,633.0	2.65	746,213	298.49	8,954,550	3,582
Electricity	$0.015 per kilowatt hour	[3]222.8	3.34	[3]25,065	375.98	[3]300,780	4,512
Total			7.18		809.19		9,710
Labor:							
Laborers per shift, 3	$5 per 8-hour day		10.00		1,125.00		13,500
Manager	$10 per 8-hour day		2.22		250.00		3,000
1 Common laborer per day	$4 per 8-hour day		.89		100.00		1,200
Social Security tax	3 percent of cost of labor		.39		44.25		531
Total			13.50		1,519.25		18,231
Total manufacturing costs			27.19		3,061.10		36,733

Fixed charges:							
Depreciation on cost of assets:[4]							
Building cost, $12,000	2 percent of cost		.18		20.00		240
Equipment, cost $38,000	12 1/2 percent of cost		3.52		395.83		4,750
Insurance and taxes	2 percent of capital		.74		83.33		1,000
Repairs on equipment	6 percent of equipment cost		1.69		190.00		2,280
Interest on $12,000 working capital	6 percent working capital		.53		60.00		720
Total			6.66		749.16		8,990
Total production costs			33.85		3,810.26		45,723
Sales costs:							
Traveling expenses			1.00		112.50		1,350
Local advertising			.25		28.13		337
Commission			2.00		225.00		2,700
Total			3.25		365.63		4,387
Total for all costs			37.10		4,175.89		50,110

[1] Quotations for October 1945. [2] Gallons. [3] Kilowatt-hours. [4] For further advice concerning depreciation, see your local Collector of Internal Revenue.

TABLE 12.--*Estimated annual income and profit on capital investment based on production of 1,350,000 square feet of 25/32-inch insulating sheathing board*

Item	Selling price for grades No. 1 and No. 2, respectively				
	$40 and $32.50	$42.50 and $35	$45 and $35	$47.50 and $35	$50 and $35
	Dollars	Dollars	Dollars	Dollars	Dollars
Income from 1,280,000 square feet of No. 1 insulating board 25/32 inch thick	51,200	54,400	57,600	60,800	64,000
Income from 70,000 square feet of No. 2 or substandard insulating board	2,275	2,450	2,450	2,450	2,450
Total income	53,475	56,850	60,050	63,250	66,450
Total cost	50,110	50,110	50,110	50,110	50,110
Net profit	3,365	6,740	9,940	13,140	16,340
Return on capital investment prior to Federal taxes, percent	6.7	13.5	19.9	26.3	32.7



(A) Vertical Section Thru Walls and Roof
(B) Horizontal Section Thru Wall

Figure 18.—Insulated masonry construction.

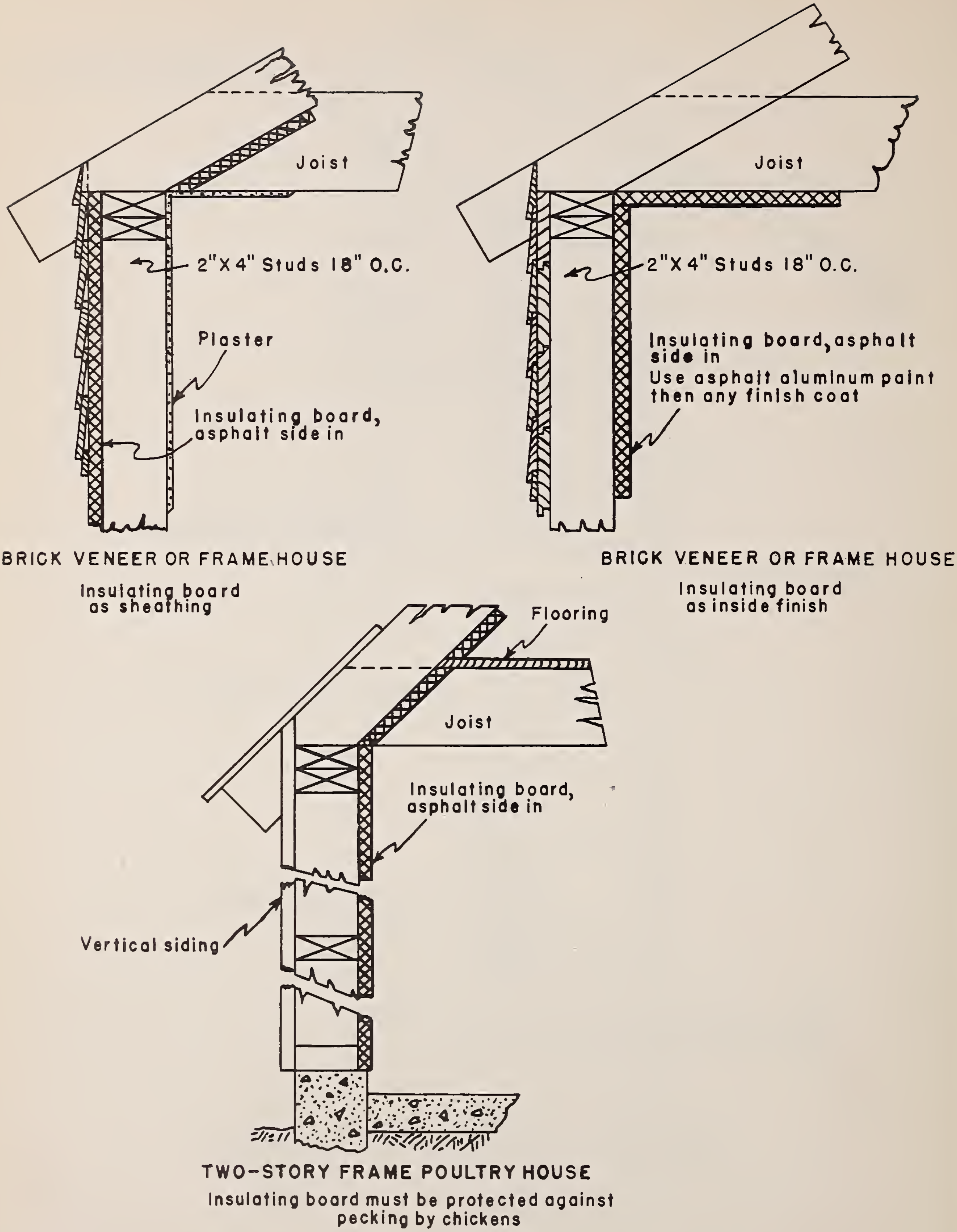


Figure 19. —Insulation on brick veneer or frame construction.

USES AND APPLICATION SPECIFICATIONS[3]

The 4' x 4' x 25/32'" sheathing board may be used in farm buildings and homes in the same way as other board-form insulating materials. In application to framing, all end joints should center over framing and boards should be spaced 1/16" to 1/8" at all ends. Use 2" galvanized nails with 3/8" or 1/2" heads.

When used under stucco as an exterior finish, a suitable stucco base such as galvanized metal lath is applied directly over the sheathing and paper, and nailed or stapled through the board into the studs.

The insulating board may be used as a plaster base for interior application in which case it will be desirable to cut the boards into 2' x 4' lath, applying the lath in staggered arrangement centering over the studs. If the weather is dry the boards should be sprinkled lightly with water and piled for 24 hours before application. All four edges of the board may be beveled to form a V-joint for producing stronger joints. Use only straight gypsum plaster. Corner and other angle joint reinforcing with metal bead and lath, as is practiced in the application of other insulating lath boards, is required.

In application where condensation of moisture within or on the insulation is likely to occur, a layer of vaporproof material should be applied on the side of the insulation board which will be warmer most of the time. For example, in a dwelling the inside is warmer than the outside during the winter. There is ordinarily no time of year when the inside temperature in a dwelling is much cooler than outside for long periods. For this reason, any serious tendency for moisture to accumulate in the insulation occurs in winter, and the insulation needs protection on the inner side. The asphalt coating on these boards retards absorption or transfer of moisture but does not prevent all transfer. Where plans call for vapor barriers, the asphalted side should be supplemented with additional asphalt coating or other barrier.

Asphalt aluminum paint provides additional vaporproofness and is the most satisfactory base paint for use on the asphalted side of the board. It may then be covered with other decorative paint when the board is used as the interior surface in a dwelling.

The accompanying diagrams, figures 18 and 19, show a few examples of application of board-form insulation in farm buildings. In cases where the insulation is imbedded in concrete, the material should be dipped in asphalt or otherwise treated so that there is a continuous coating on all surfaces, including the edges and corners.

In livestock buildings, board-form insulation should be protected against abrasion or attack by animals. Chickens peck such surfaces and may destroy the material if they can reach it. Screen wire, wood or cement asbestos boards, or cement plaster on metal lath may be applied over the insulation where there is danger of pecking. Hogs or cattle may habitually rub against certain areas in a building and wear away the materials. No board-form insulation should be exposed to damage from such causes.

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[3]Prepared by Wallace Ashby, head, and W. V. Hukill, agricultural engineer, Division of Farm Buildings and Rural Housing, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

For the purpose of general recommendations for insulation of farm buildings, the United States is commonly divided into four climatic zones. The four zones are indicated on the accompanying map, figure 20. In general, insulating materials are recommended for various farm buildings in the zones indicated below:

Structure	*Zones in which insulation is desirable*
Farm houses	All zones
Dairy barns	Zones 1 and 2
Laying houses	Zones 1, 2, and 3
Hog houses	Zones 1 and 2
Fruit or vegetable storages	All zones
Milk houses	All zones

The thickness of insulation should be determined for a given structure in accordance with the usage, climate, and type of structure. When a building is planned, specific requirements for the particular building should be used in deciding the amount of insulation. As an example of insulation requirements, the following tabulation from U.S.D.A. Circular 722, Functional Requirements in Designing Dairy Barns, shows suggested minimum insulating values[4] of insulation for dairy barns:

Stable size	Zone 1		Zone 2		Zone 3	
	Walls	Ceiling	Walls	Ceiling	Walls	Ceiling
Large	4.0	7.0	3.0	5.0	2.0	3.5
Small	6.0	7.0	4.0	5.0	2.0	3.5

Insulation requirements are frequently expressed in units of difference in degrees temperature required for transmission of 1 B.t.u. per square foot per hour. In terms of this unit, most board-form materials have an insulating value of about 3.5 for each inch of thickness.

A tight frame wall with paper and boards on both sides of 2" x 4" studs may be expected to have an insulating value of about 4.0 with no added insulating material.

In buildings for farm animals, one of the problems in cold weather is to prevent condensation on the walls and ceiling. Frequently the ceiling is insulated more heavily than the walls so that condensation, if any occurs, will take place on the walls and not on the ceiling. In deciding how much insulation to apply in a given building, it is suggested that the following bulletins be consulted:

[4]The insulating value represents the number of degrees difference in temperature on opposite sides of a wall that will cause 1 B.t.u. of heat to flow through an area of 1 square foot in 1 hour.

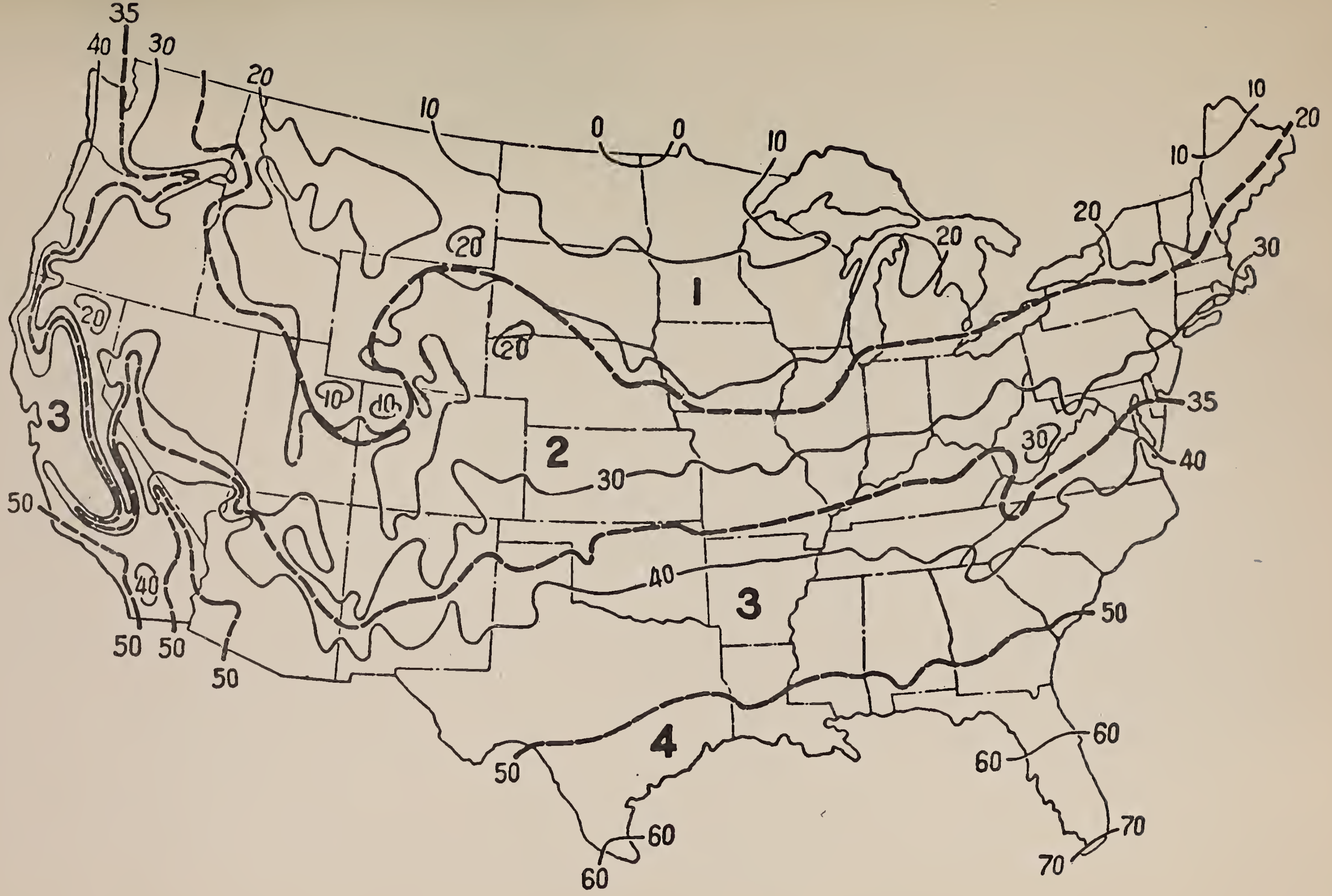

Figure 20.—Average January temperatures (°F.) and temperature zones.

U. S. Dept. of Agriculture Circular 701, Hog Housing Requirements

U. S. Dept. of Agriculture Circular 722, Functional Requirements in Designing Dairy Barns

U. S. Dept. of Agriculture Circular 738, Functional Requirements in Designing Laying Housing for Poultry

U. S. Dept. of Commerce Report, Insulation on the Farm

For details on application of insulating board products, see:

"Sweets File-Architectural" published by Sweets Catalog Service, 119 W. 40th St., New York 18, N. Y.

Further reference is made to:

"Farm Building Insulation" published by The Insulation Board Institute, 111 West Washington, Chicago 2, Ill.

APPENDIX

Apparatus and Methods Used in Laboratory Studies on Insulating Board Manufacture

The equipment required for the commercial evaluation of fibers for producing insulating building materials is relatively simple and consists of the following: (1) A cooker or digester, (2) a hammer-mill shredder, (3) a washer, (4) a small hydraulic press, (5) a mixing tank, (6) a board-forming machine, (7) a scale for weighing, (8) a drying oven, (9) some cans for mixing and collecting water, and (10) testing machines for determining thickness, and tensile and transverse strengths of the board, together with a stop watch, a freeness tester, and some simple chemical apparatus.

COOKER

The cooker used is one in which 12 pounds of dry straw can be cooked. This cooker is used also for producing paper pulps and is shown in figure 21.

SHREDDER

The cooked pulp is defibered while wet by passing it through a hammer-mill shredder. The degree or splitting of the fiber bundles and of shortening the fibers is regulated by the size of the round holes in the bottom plate of the shredder.

WASHER

Pulp from the shredder may be washed in a box containing a wire-cloth bottom by using water from a hose to wash out the chemicals. A rotary washer is convenient when larger lots of pulp are to be handled.

PRESS

A small hydraulic press, shown in figure 22, is used for dewatering the washed pulp, after which the pulp cake is broken up by hand and placed in a can having a tight cover. A sample of the pulp is dried at 217°-221° F. for several hours to determine its moisture content. The press is also used for expressing water from the wet board.

MIXING TANK

Sufficient moist fiber is weighed out to make one board and is placed in a can which is supplied with a stirrer. Water is added to the fiber in the can so that a ratio of 98 parts of water to 2 parts of dry fiber results. The mixture is stirred for about 15 minutes to insure a uniform fiber suspension.

BOARD-FORMING MACHINE

A board-forming machine, figure 23, is required which produces a board of 11" diameter and of the desired thickness. It consists of a grooved aluminum base to which is connected an outlet pipe and valve; two round brass plates 1/16" thick, in which slots 1/8" wide and 1/2" long on 1" centers are drilled; two 16-mesh galvanized wire screens; two round pieces of papermaker's felt; and four or more metal rings, 11" in diameter and 4" high, flanged at top and bottom to fit together. The machine is assembled by placing the drilled plate over the grooved surface of the base. A wire screen is then placed on the drilled plate and the four rings are fitted together on the base to form a head box.

Boards are formed in the following manner: The outlet valve on the base is closed, and a fiber suspension of definite consistency (from 0.5 to 2 percent) is well mixed and poured into the head box. This suspension is gently stirred with a stick for about 30 seconds, and the valve is opened wide. The time necessary for drainage of water is noted. During drainage it is often necessary to wash down fibers clinging to the sides of the head box. For very accurate work the volume of this wash water may be noted. The machine must be level so that the fibers settle uniformly. When drainage is complete the three upper rings are removed, care being taken that they carry no fibers, and a 16-mesh wire screen, followed by a drilled plate, is laid on top of the wet mat of fibers. On top of this is placed a round aluminum block about 1" thick. The board is placed in the hydraulic press shown in figure 22.

The pulp mass at this point will be closely representative of that emerging from the cylinder or wire of a commercial board machine. The proportion of water drained represents that which will be returnable to the mill white water system at this point. Drainage rates of boards made from different fiber preparations indicate their relative water-holding capacities and filtration characteristics.

In all commercial processes for insulating board manufacture it is necessary to pass the formed sheet through press rolls to remove as much water as possible, commensurate with the desired properties of the final dry board. To duplicate this operation the board is pressed in the laboratory board-forming machine under hydraulic pressure. The water pressed out during the operation is collected in a weighed can of about 1-gallon capacity. The board is put under pressure gradually up to about 25 p.s.i. and, when the drainage of water has slowed down to a dribble, the pressure is released, and the pulp mat is removed and weighed. Knowing the original weight of oven-dry fiber used (from consistency of pulp and water mixture), the moisture content of the board at this point can be calculated. The weight of the water extracted from the board in the press, added to the weight found in the wet board, will give the amount of water in the board at the end of the free drainage period during board formation. Papermakers' felts cut to circles of 11" diameter are wetted and placed on each side of the wet board and on the outside of each of these is placed a drilled metal plate. This combination is returned to the press, a block being used to replace the base of the board machine and another block being placed on top to fill the press opening. The board is alternately pressed and weighed until the desired moisture content is reached.

The amount of water in the wet board as it goes into the drier is important from the standpoint of drying costs. For example, a board containing 50 percent fiber and 50 percent water requires the evaporation of 1 ton of water per ton of dry board; one containing 75 percent water requires the evaporation of 3 tons per ton of dry board; and one containing 80 percent water, the evaporation of 4 tons of water.

DRIER

The wet board is now dried to constant weight in an oven in which air is circulated at a temperature of about 320° F. The board is cooled in a closed container and weighed, and the average thickness of the board is determined by means of an Ames dial gage. From the dry weight, thickness, and area of the board its apparent density relative to water is obtained.

TESTING

Samples cut from the board are tested on a machine for measuring transverse and tensile strengths.

Sizing the board to produce water resistance by the use of rosin size and alum may be studied with this laboratory equipment. The white water, which contains the excess of alum, is used instead of fresh water for making the fiber suspension.

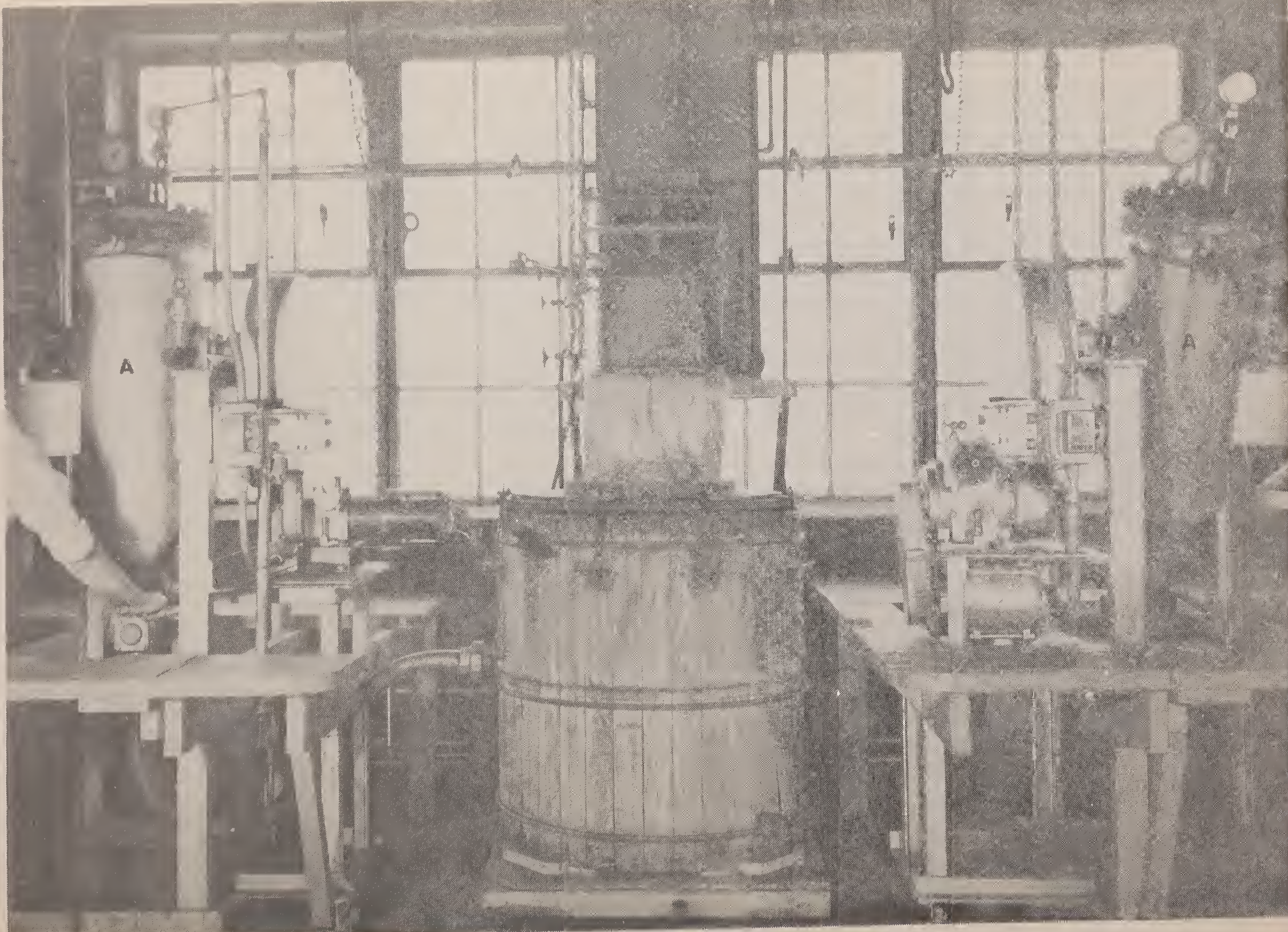

Figure 21. —Pilot plant rotary cookers (A).

Figure 22.—Hydraulic press for dewatering pulp (A), laboratory board forming machine (B), container for waste water (C).

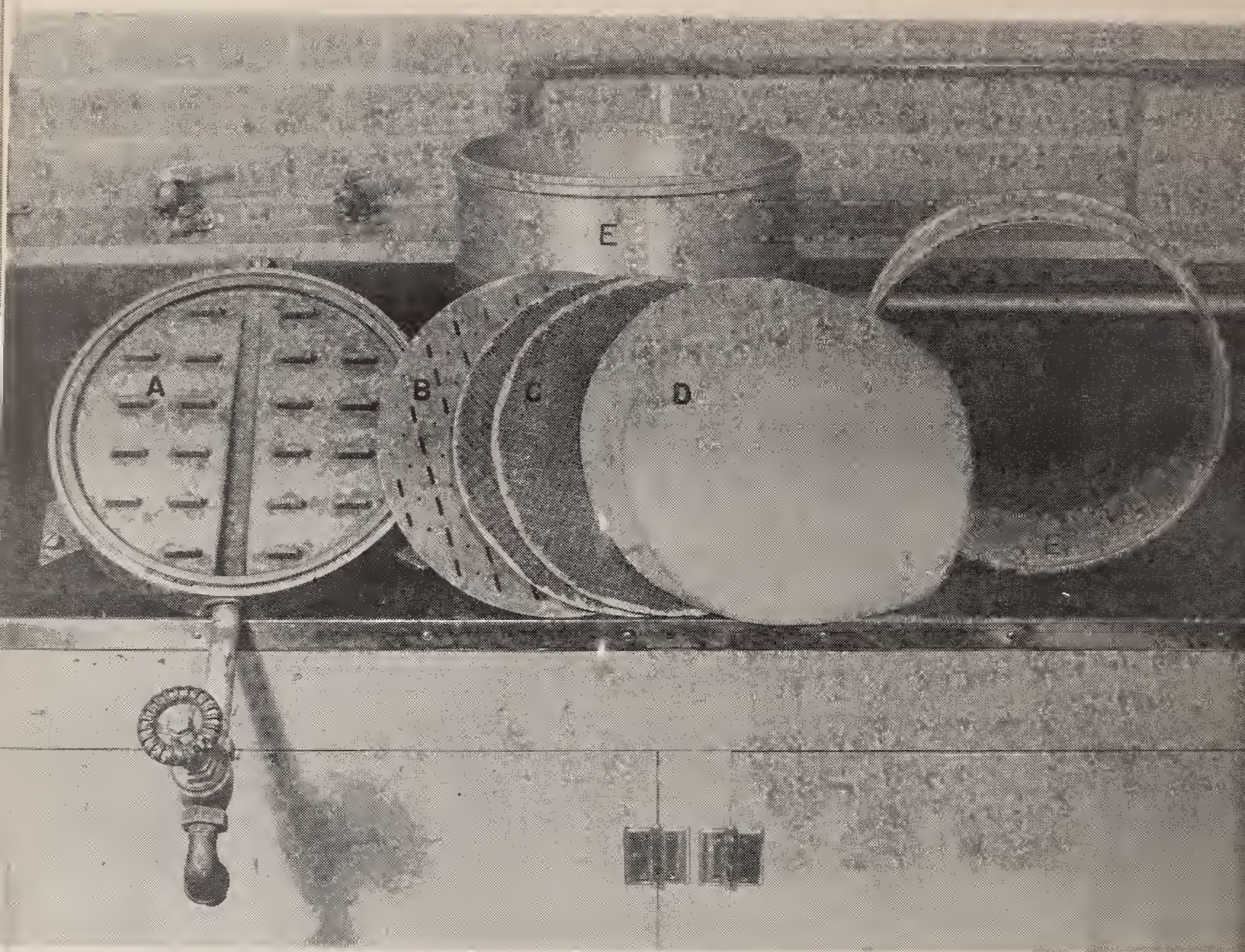

Figure 23.—Laboratory board-forming machine: base with outlet pipe and valve (A), brass plate with slots (B), 16-mesh wire screens (C), papermaker's felts (D), rings to serve as head box (E).